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TRANSATLANTIC WIRELESS TELEGRAPHY has been successfully accomplished by Marconi, messages having been transmitted from the station at Table Head to that at Poldhu, Cornwall, and public announcement of the success being made on Dec. 21. As our readers will remember, the letter S was transmitted across the Atlantic a year ago; but various delays have intervened before the apparatus was ready for the successful transmission of extended messages. It is stated by the representatives of the Marconi company in London that transatlantic messages have been sent back and forth since Dec. 15, and that commercial business can be handled at the rate of 1,000 words an hour as soon as the necessary land connections can be made.

UNDERGROUND TELEGRAPH LINES on trunk routes are being laid in England as reserves in case of any breakdown of the overhead lines. The cities of London, Manchester and Liverpool will soon be connected by such emergency cables, the larger part of these lines being already completed. The underground line from London to Birmingham has been completed for some time, as have also lines between Liverpool and Manchester, via Warrington. The section from Birmingham to Warrington is at present under construction. The telegraph in England is all government owned, being in charge of the Post Office Department.

ELECTROLYTIC CHLORINATION OF GOLD ORES is reported to be a commercial success in a plant at the Wall Street mining camp, Colorado. The inventor of the process is John Greenwald, a Cornell University graduate. The process consists in decomposing a solution of common salt by electrolytic action, and using the chlorine so produced to dissolve out the gold. Colorado mining engineers are said to regard the process as an epoch-making one in the history of gold mining.

LAKE ORE SHIPMENTS for 1902 aggregate 27,450,000 tons, according to the "Iron Age." This represents a huge increase over the records of any previous year. For 1899, 1900 and 1901, the shipments were 18,250,000, 19,120,000 and 20,890,000 tons respectively. Nearly half the present year's output came from the Mesaba range, its contribution being 13,293,000 tons. The Menominee came next with 4,270,000 tons, and the Gogebic and Marquette each sent a little over 3,500,000 tons.

THE FIRST LARGE SHIPMENT of Minnesota iron ore to St. Louis by rail is now being made. The shipment is in the nature of an experiment, that may lead, however, to very large all-rail shipments to furnaces in the Mississippi valley.

ALASKA COAL IS NOW USED AT DAWSON, the coal being mined from a 6-ft. vein at Forty Mile Creek. It is stated that this coal mine is more of "a gold mine" than many gold mines. Bituminous coal is found in many parts of Alaska and anthracite also in some sections.

THE OIL WELLS OF ALASKA, at Cook's Inlet, are producing oil at a rate that is causing a rush to locate as many acres as possible before the winter sets in. New York capitalists are said to be among the most enthusiastic oil seekers, and are in the field in large force with money and machinery. This oil field, as far as prospected, extends along the coast for 150 miles and into the interior from 50 to 75 miles. The Nome, or Behring Sea, fleet of 40 vessels cleared from Nome waters last week, leaving the country cut off from the outside world till next May, when navigation opens again.

THAT GOVERNMENT SURVEYS OF ALASKA should be immediately made is recommended by Governor Brady, who points out that now all titles to coal, oil and timber lands are insecure, and that persons holding such property do not dare to make extensive improvements until public surveys have been made. It will be news to many to know that as yet no clear title can be had to any Alaska lands except mineral claims.

THE MOST SERIOUS RAILWAY ACCIDENT of the week, and by far the most serious for many months, occurred on the Southern Pacific Ry., near Byron Hot Springs, Cal., on the evening of Dec. 20; some 20 to 25 persons were killed—the exact number being not yet known. A fast through train ran at high speed into the rear end of an accommodation train. Little is known as to the cause of the accident; the local had stopped at the station, and the through train had been back-signaled, and had responded by applying brakes. The collision completely telescoped the rear two cars of the local.——Rather more than the usual number of fatal railway accidents is to be recorded for the past week. Next to the Southern Pacific wreck, the worst was a collision between a passenger train and an extra freight on the Chicago, Burlington & Quincy Ry., near Table Rock, Neb., on Dec. 17. Four persons are reported killed; no particulars as to cause of the collision are given in the news accounts. On Dec. 22 a helping engine on the Cincinnati, Hamilton & Dayton Ry. got beyond the control of its engineer near Connersville, Ind., ran away and struck a freight train; reversed, and when at very high speed struck another freight. Two men were killed by the wild engine in its two trips.

A NEW HIGHWAY BRIDGE FELL at Trenton, N. J., on Dec. 22. The structure, a span of about 100 ft., over the Assinbink Creek, and built by the Berlin Construction Co., of Berlin, Conn., had just been completed and was not yet turned over to the county. No one was killed in the fall. Further details of the failure are not available at present.

DROPPING A BOX OF DYNAMITE by a miner who stumbled while carrying it, resulted in the killing of four men and the maiming of eight others recently in Baltimore Mine No. 8 of the Lehigh & Wilkes-Barre Coal Co. The dynamite had just been lowered down the shaft, and the miner was carrying it to the tool house.

X-RAYS TO CATCH MINT THIEVES is the latest application of Roetgen's great discovery. The Mikado of Japan is reported to have ordered an X-ray apparatus for the purpose of discovering the presence of surreptitiously swallowed coins in the stomachs of suspected workers in the mint.

A DEEP-WELL PUMPING PLANT has recently been installed at the water station of the Atchison, Topeka & Santa Fe Ry. at San Bernardino, Cal. The well is 480 ft. deep, 12 ins. diameter. Water stands at 70 ft. below the surface when the pump is at work, and is elevated through 120 ft. of 5-in. pipe to the top of a standpipe 60 ft. high and 24 ft. in diameter, making a total lift of 130 ft. A 15-in. Triumph piston pump is used, having a 7-in. cylinder in the well. This is driven by an 11-HP. Foos gasoline engine operated with California distillate costing 7½ cts. per gallon. The pump makes about 38 revolutions per minute, and raises 180 gallons per minute, or 10,800 gallons an hour, with an actual development of 8 HP. and a fuel consumption of 8 pints of distillate. The cost of operation is 7 mills per 1,000 gallons lifted 130 ft., which is claimed to be 50% less than by any other style of machinery. This cost does not include attendance, as the engineman was in charge of a boiler near by, and his duties were increased only to the extent of starting, stopping and oiling the pumping plant. This plant was put in by the S. W. Luitwieler Co., of Los Angeles, Cal., by whom the above information was furnished.

LOW WATER [illegible] S of California streams during 1902 were made as extensively as possible by the U. S. Geological Survey, and the results may be obtained by applying to Mr. J. B. Lippincott, M. Am. Soc. C. E., Resident Hydrographer, Los Angeles, Cal.

THE WATER POWER DEVELOPMENT on the American and Canadian sides of the Sault Ste. Marie now amounts to a total of 100,000 HP. As this is a larger amount of power than it is expected to utilize locally, the Consolidated Lake Superior Power Co. is now studying the question of transmitting a part of the power to various distances. It has even been proposed to transmit it as far as Detroit, Mich., but nothing definite has yet been decided.

A 3,000-HP. GAS ENGINE is to be exhibited at St. Louis by the Cockerill Co., of Seraing, Belgium, the firm which has taken the lead in the development of the use of blast-furnace gas for blowing engines in Europe.

STEAM MOTOR CARS USING OIL AS FUEL are to be tried for passenger traffic on French railways, according to a cable despatch to the New York "Times." The firm of Gardner et Serpollet is building the cars, which will have a seating capacity of 40 persons each. Short trains of three such cars each are to be run on high-speed schedules over short divisions.

THE U. S. MONITOR "NEVADA," had her official trial trip, over the Cape Ann course, on Dec. 18. The contract speed was 11.5 knots, whereas she made an average speed of 12.95 knots over water that was neither smooth nor rough. The course was 13.2 nautical miles and return; the best speed was 13.6 and 13.9 knots. The trial was made on natural draft and the engines worked admirably; though the decks were practically covered by foam and water during much of the run, and her steering was very bad. The "Nevada" was built at the Bath Iron Works for $960,000. She is 232 ft. long and 3,230 tons displacement, and her trial draft was 12 ft. 7 ins.

A TURNTABLE operated by a compressed air engine is in use at the West Oakland shops of the Southern Pacific Ry. The motor in use was designed at the shops. It works at 100 lbs. pressure and uses about 8½ cu. ft. of free air in turning a locomotive. The cost of the device was about $250. It is described and illustrated in "The Railway and Engineering Review" of Dec. 13.

THE EIGHT-HOUR COMPULSORY ACT of April 16, 1900, has been declared unconstitutional as applied to municipal contract work in Ohio. This decision was rendered by the State Supreme Court, on Dec. 2, in a suit brought by the city of Cleveland against the Clements Brothers Construction Co., contractors for sewer work in Cleveland. The city tried to collect a penalty of $10 a day on account of the employment of men for days exceeding eight hours in length.

A SAND BLAST FOR CLEANING THE WALLS of the Treasury Building at Washington, D. C., is reported to have been used with entire satisfaction. The compressed air sand blast removes not only the dirt, but a thin layer of stone also, leaving a face that looks like new masonry. Men manipulating the blast wear hoods to keep the sand and grit out of their eyes and lungs.

A SIX-MASTED SCHOONER WAS LAUNCHED at Bath, Me., on Dec. 17, at the yards of Percy & Small. The vessel was christened "Addie M. Lawrence."

LABORATORY VESSELS OF FUSED QUARTZ are being made and sold by two German makers, Heraeus, of Hanau, and Siebert & Kühn, of Cassel, according to the London "Electrician." The oxyhydrogen blowpipe flame is used for the work, flasks, tubes, etc., being made. The "Electrician" continues:

> Most characteristically, these enterprising makers appear to be ignorant that all this has been done by Boys & Shenstone some time ago, and more recently by Hutton, the latter using the electric furnace. The work of these three has, of course, been confined to the scientific side of the question, and it seems a pity that the ideas and experiments original with them should not have been adopted and applied by some instrument maker in this country. It may be added that there is a larger field for fused quartz than for making laboratory apparatus, and our manufacturers will be wise to seize it in good time.

AT THE NIAGARA FALLS MEETING of the American Electrochemical Society, Mr. R. S. Hutton, of Manchester, England, described his work with fused quartz, and made it clear that the practical difficulties in the way of producing apparatus of fused quartz are very great. The commercial production of apparatus made of fused quartz must be reckoned as an achievement very creditable to the German makers referred to; the passage above quoted seems to show a rather unscientific envy of this achievement, on the part of our English contemporary.

THE DESIGN AND CONSTRUCTION OF A 50-FT. BRICK ARCH CULVERT ACROSS ROCK CREEK, WASHINGTON, D. C.

By W. J. Douglas.*

A brick arch culvert of 50-ft. clear span and 200 ft. long between portals has recently been constructed at Washington, D. C., to carry the waters of Rock Creek through the earth fill now being made to carry Massachusetts Ave. over that stream. The history of the inception of this work and an account of its design and construction will perhaps be of interest to engineers.

In 1893, Captain, now Major, Wm. T. Rossell, at that time Engineer Commissioner of the District of Columbia, assisted by Capt., now Major, J. S. Lusk, and Capt., now Lt.-Col., G. J. Fiebeger, all of the Corps of Engineers, U. S. A., pursuant to an act of Congress, prepared general plans, specifications and estimates for converting Rock Creek, below the north line of Massachusetts Ave., a distance of 7,350 ft., into a closed sewer, and filling in between banks of the creek, and further prepared an estimate of the value to the government of the probable cost of condemnation of the land thus reclaimed. Rock Creek, in a straight line from its head to its mouth, traverses a distance of 22 miles. The area of its watershed is 77.13 square miles. This area is practically all agricultural land, possibly ⅛ wooded, and a small section in the immediate vicinity of Washington is suburban in its character and will ultimately be urban. The highest recorded freshet discharge at the mouth of the creek is about 10,000 cu. ft. per second.

CALCULATION OF FLOOD DISCHARGE.—In the absence of actual gagings of the Rook Creek flood of 1889, the highest freshet known, Captain Lusk endeavored to establish approximate limits between which, as a probable maximum and minimum, the discharge due to a rainfall of exceptional severity and extent over that valley may be supposed to lie. The limits decided upon by Captain Lusk were as follows:

(1) As to the probable lower limit, it is not unreasonable to provide against 6 ins. of rainfall uniformly discharged in 24 hrs., from the whole of so much of the watershed as is rural in character and is likely to remain so for a considerable period. For 63.39 sq. miles the discharge under this supposition would be 10,227 cu. ft. per sec. Applying McMath's formula in the form

$$Q = .75 \times 2.75 \sqrt[6]{10\ A^4}$$

to that portion of the watershed, or 8,792 acres, which will almost certainly be paved and built upon to a greater or less extent before the lapse of many years, a discharge of 4,674 cu. ft. per second results. The total for the basin is 10,227 + 4,674, or 14,901 cu. ft. per sec.

(2) To fix the higher limit I have supposed the basin, 49,363.2 acres, to be divided into five areas, equal in size, built upon and paved, similar in slope and surface conditions, and all converging to a single point, viz., the head of the proposed waterway. McMath's formula as above is applied, s being assumed as equal to 10, and A as equal to 9,872.64 acres. The last-named area is within the scope of McMath's formula, as discussed by the author in Volume XVI. "Transactions of the American Society of Civil Engineers." The result is 5,128 cu. ft. per sec. for each of the smaller areas, or 25,640 cu. ft. per sec. for the whole. I have no doubt that this result is greater than any discharge that can be expected to take place except under conditions which cannot possibly be foreseen.

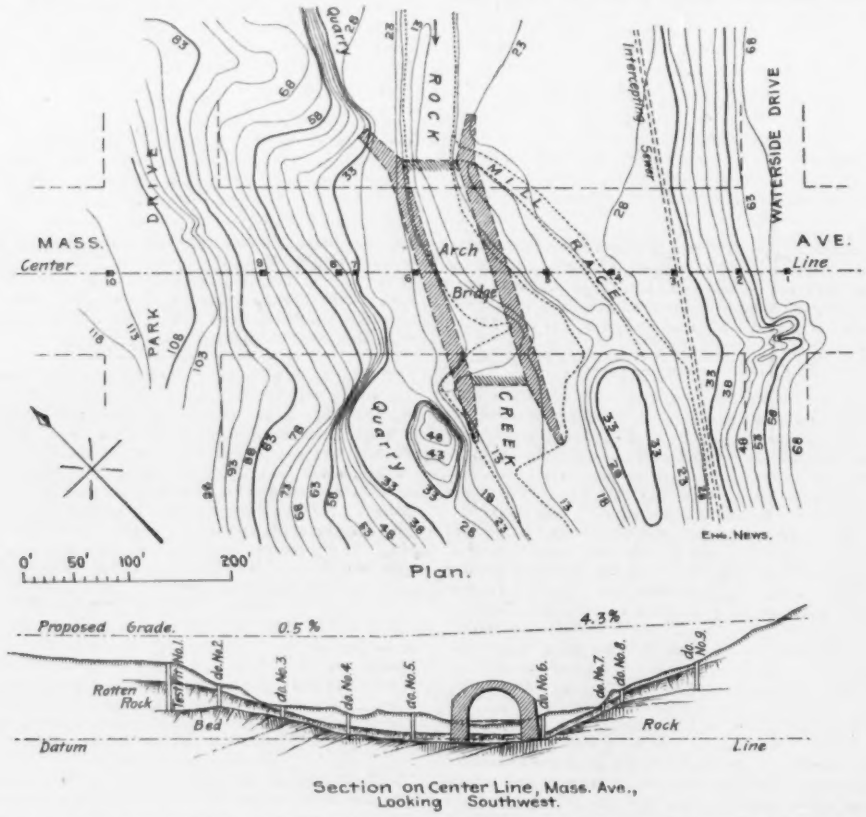

FIG. 1. PLAN AND PROFILE OF MASSACHUSET TS AVE. FILL AND CULVERT OVER ROCK CREEK, WASHINGTON, D. C.

Between these limits of, practically speaking, 15,000 and 26,000 cu. ft. per second, Captain Lusk obtained the following results:

(1) McMath's formula, as above, applied to the Rock Creek basin, all of it being assumed as likely to take on an urban character: Discharge = 18,583 cu. ft. per sec.

(2) Same as in (1), except that McComb's formula for large sewer areas. Q = 5.2375 . A⅘, is applied. (A = 49,363 acres.) Discharge = 17,531 cu. ft. per sec.

(3) Nine inches of rainfall uniformly discharged in 24 hrs. from the whole basin: Discharge = 18,605 cu. ft. per sec.

(4) Six inches of rainfall uniformly discharged in 24 hrs. from the entire rural watershed (63.39 sq. miles) gives 10,227 cu. ft. per sec. Divide the remainder, 8,792 acres, into natural drainage subareas and apply Burkli-Ziegler's formula (s = 10, c = .75, r = 2.75) Q = 5,980 cu. ft. per sec. Whole discharge = 10,227 + 5,980 = 16,207 cu. ft. per sec.

(5) Same as in (4), except that McMath's formula, as above, is applied to the drainage surfaces: Discharge = 17,664 cu. ft. per sec.

(6) Same as in (4), except that the curve of the Engineer Department of the District of Columbia is applied to the drainage subareas: Discharge = 18,913 cu. ft. per sec.

(7) Same as in (4), except that the curve of the Board of Sanitary Engineers on the sewerage of the District of Columbia is applied to the drainage subareas. (See Plate VIII., Ex. Doc. 445, H. R., Fifty-first Congress, first session.) Discharge = 19,949 cu. ft. per sec.

(8) Nine inches of rainfall uniformly discharged in 24 hrs. from 63.39 sq. miles (rural area), and McMath's formula, as above, applied to 8,792 acres (urban area): Discharge = 20,014 cu. ft. per sec.

(9) Nine inches of rainfall uniformly discharged in 24 hrs. from 60.81 sq. miles (Maryland area), and McMath's formula, as above, applied to 10,447 acres (District of Columbia area): Discharge = 20,083 cu. ft. per sec.

(10) Apply Burkli-Zeigler's formula, as above, to the drainage subareas comprising the 8,792 acres; Q = 5,980 cu. ft. per sec. Also apply McMath's formula, as above, to the remaining 40,571 acres of watershed; Q = 15,884 cu. ft. per sec.: Discharge = 15,884 + 5,980 = 21,864 cu. ft. per sec.

(11) Same as in (10), except that McMath's formula, as above, is applied to the drainage subareas comprising the 8,792 acres: Discharge = 15,884 + 7,437 = 23,321 cu. ft. per sec.

(12) Same as in (10), except that the curve of the Engineer Department of the District of Columbia is applied to the drainage subareas comprising the 8,792 acres: Discharge = 15,884 + 8,686 = 24,570 cu. ft. per sec.

(13) Twelve inches of rainfall uniformly discharged in 24 hrs. from the whole basin: Discharge = 24,887 cu. ft. per sec.

(14) Same as in (10), except that the curve of the Board of Sanitary Engineers on the sewerage of the District of Columbia is applied to the drainage subareas comprising the 8,792 acres: Discharge = 15,884 + 9,722 = 25,606 cu. ft. per sec.

The following results are interesting as showing the wide range of results obtained by applying the various formulas cited to the Rock Creek Valley. The symbols used are as follows:

Q = total discharge in cubic feet per second;
A = area of watershed = 77.13 sq. miles = 49,363.2 acres;
L = length of watershed = 22 miles;
B = average width of watershed = 3.51 miles;
N = a coefficient varying from 0.37 to 1.95; here assumed as 1.95.

(1) The O'Connell Formula:
Q = − 45.736 + 2,097.28 + 457.96 A = 4,707 cu. ft. per sec.

(2) The Fanning Formula:
Q = 200 A = 7,477 cu. ft. per sec.

(3) The Dredge Formula:
Q = 1,300 = 12,771 cu. ft. per sec.

(4) The Craig Formula:
Q = 440 B N hyp. log. = 21,098 cu. ft.

(5) The Dickens' Formula:
Q = 825 A = 21,472 cu. ft. per sec.

While the results of no single formula are in themselves to be relied upon in determining the possible extreme discharge from a basin of the size of, and subject to the complex surface conditions which will ultimately prevail in the Rock Creek Valley, Capt. Lusk is inclined to place confidence in McMath's formula, when applied to large areas likely to become urban in character.

On the basis of the above calculation it was decided by Captain Lusk to design the sewer so as to carry 18,000 cu. ft. per second when running full, and 25,000 cu. ft. per second when running under a 6-ft. head. The span required for this discharge was determined as 50 ft. (full cen-

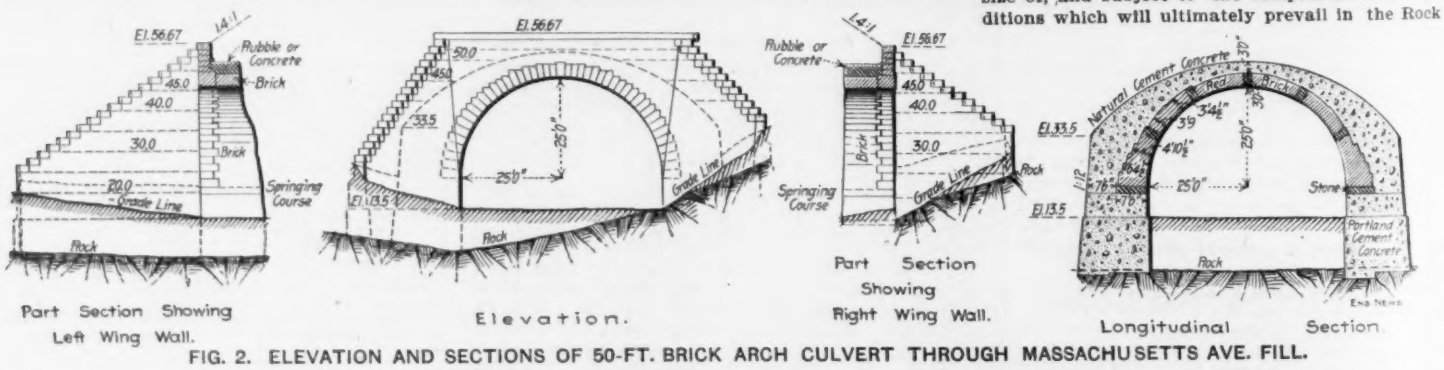

FIG. 2. ELEVATION AND SECTIONS OF 50-FT. BRICK ARCH CULVERT THROUGH MASSACHUSETTS AVE. FILL.

*Engineer of Bridges, District of Columbia, Washington, D. C.

ter), with a total rise of 32.5 ft. and a cross-section of 1,250.5 sq. ft. Captain Lusk called attention to the fact that a freshet of the maximum discharge calculated, would probably bring down large trees, portions of iron and wooden bridges and other débris, in large quantity. It is further estimated that if the sewer became completely stopped up, it would take about 4 hours to fill up to the level of the roadway, which is at an elevation of about 80 ft. above the bed of the creek. The estimated cost of the work was as follows:

Cost of covered waterway	$2,990,412
Sewer extensions	51,500
Damages	150,000
Condemnation value of land	4,112,545
Filling and grading	2,083,324
Contingencies	512,523
Total cost	$9,900,304
Selling value of land	5,496,203
Net cost	$4,404,101

All of the foregoing data is taken from the "Report of the Engineer Department of the District of Columbia, 1893."

Captain Beach's idea was to construct about 200 ft. of this sewer or culvert (Figs. 1 and 2) and to fill above with earth. This culvert would thus be the first step in the arching of the entire creek from this point to the river, which might be carried ahead at such time as deemed advisable by Congress. By using the culvert-bridge construction, a step was not only taken toward the ultimate arching of the entire creek to the river, but a permanent bridge was assured at the point desired at a cost considerably less than that of a steel bridge of reasonably ornate type. The total estimated cost of the culvert-bridge was $225,000, of which amount $60,000 represented the cost of filling in above the arch. This filling, which is now being removed from certain streets in the immediate vicinity of the bridge, should be considered as a charge against the grading of streets, which would reduce the actual cost of this type of bridge to $165,000, or $34,000 less than that of a first-class steel bridge.

The present structure was designed and constructed under the direction of Capt. Lansing H. Beach, Engineer Commissioner, and Captain H. C. Newcomer, Assistant, and Mr. C. B. Hunt, Computing Engineer. The entire masonry structure was constructed by the Brennan Construction Co., of Washington, D. C., at a cost to the government of $132,000. Work was begun August 23, 1900, and completed December 16, 1901.

The foundations of Portland cement concrete were carried to solid rock, and the Portland cement concrete was carried up to a point 20 ins. below the springing line of the arch. Upon this abutment rests a course of springing stones, 20 ins. high, 7 ft. 6 ins. deep, and from 20 ins. to 48 ins. wide, on the showing face. Upon these stones the brick arch springs, with a thickness of 85½ ins., backed by about 7 ft. 6 ins. of natural concrete, making a total thickness at the springing line of 15 ft. The thickness of the brick arch at the crown is 3 ft., and that of the backing 3 ft., making a total of 6 ft. at the crown. It is obvious that this arch is unusually strong, but the importance of a permanent structure of unquestioned stability under all possible conditions demanded more than ordinary strength.

The up stream facade and wing walls, which were faced with Port Deposit granite (the springing course stones were from the same quarry) from the McLenahan quarries, were backed with Portland cement concrete. The down stream facade and wing walls were faced with the same kind of stone, laid as second-class work and backed with rubble, as it is probable that at some future time the culvert will be extended to the river. The south wing walls have only the splay caused by the diminution in the thickness of the walls on account of the corresponding diminution in the height, so that practically all the masonry in each wall may be used as part of the abutments of the arch when extended as contemplated.

The bridge is built on a skew of 17°. The wing walls have a batter on their faces of 1 in, in 12 ins., which passes through the springing lines of the arch, at their intersection with the face walls. The design for the curve of the wing walls at the down stream end of the bridge, and the details of the arch, coping, and bond stones are herewith submitted. At the intersection of the wing walls with the face walls at least every fourth stone

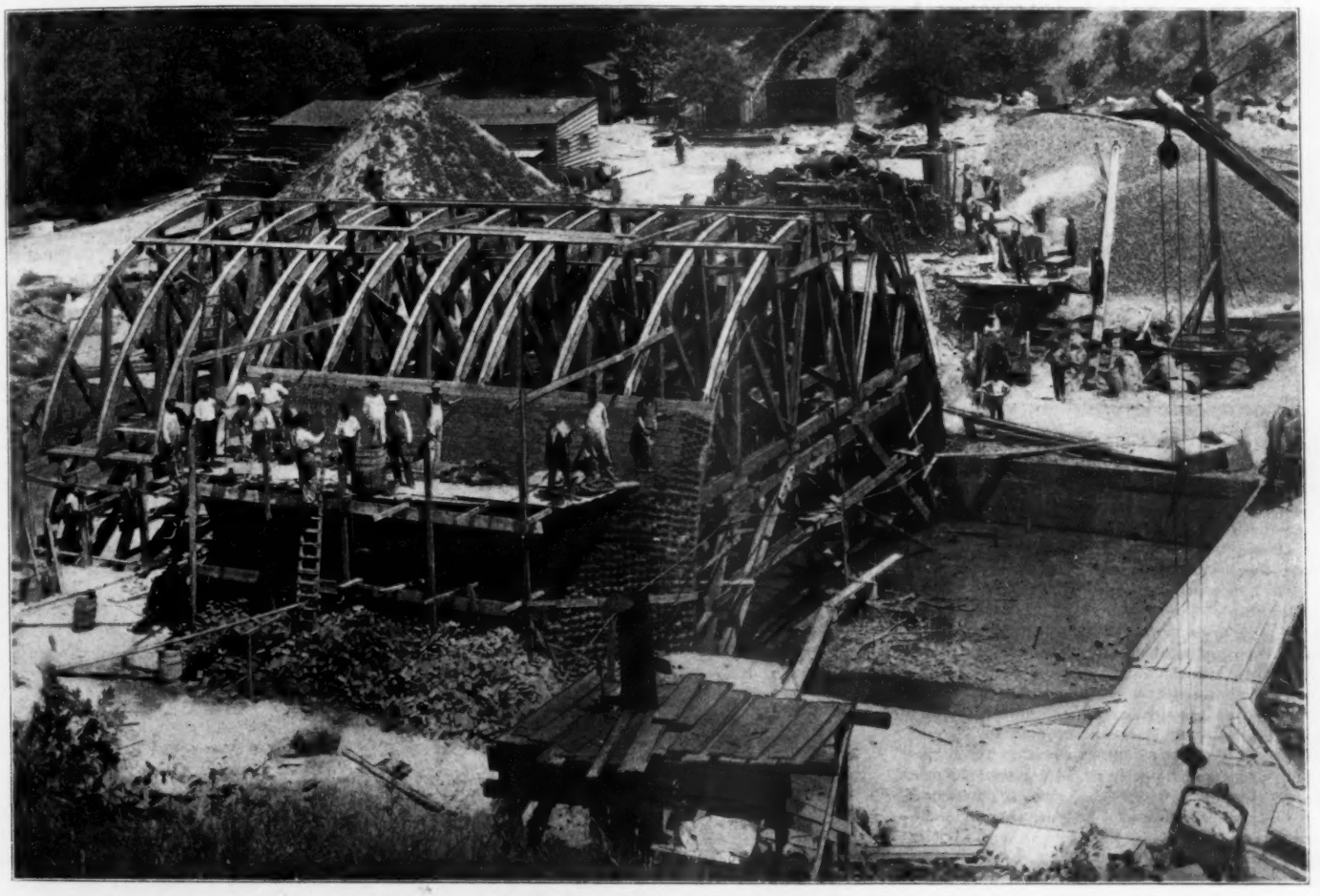

FIG. 3. GENERAL VIEW OF ARCH CENTER IN POSITION AND BRICKWORK IN PROGRESS.

GENERAL DESCRIPTION OF STRUCTURE.—In 1897, pursuant to an act of Congress, Capt. D. D. Gaillard, Corps of Engineers, U. S. A., through the Chief of Engineers of the Army, submitted to Congress plans and estimates for erecting a stone arch bridge, and also a steel bridge with stone foundations, across Rock Creek, on the line of Massachusetts Ave. The estimated cost of the stone bridge was $568,545, and of the steel bridge $199,204.

In 1898, $25,000 was appropriated toward the construction of foundations for a bridge across Rock Creek, on the line of Massachusetts Ave., but no type of bridge was specified. Capt. Lansing H. Beach, Corps of Engineers, U. S. A., who at that time was the Engineer Commissioner of the District of Columbia, decided not to build either a masonry or a steel bridge, but a culvert-bridge of the size recommended by Captain Lusk for the covered waterway or sewer which was to extend from Massachusetts Ave. to the river, the data for which is given in a general way at the beginning of this article.

	Price.		Remarks.
Excavation: Earth	$0.55	a cu. yd.	Too low.*
Excavation: Rock	2.00	" "	Too low.†
Concrete—Portland—for foundations and backing:			
First-class masonry	5.64	" "	Rather low.‡
First-class masonry (facing)	22.00	" "	
Second-class " "	19.00	" "	
Ring stones	40.00	" "	
Coping	40.00	" "	
Springing course stones	38.00	" "	
Portland-cement rubble§	6.75	" "	
Red brick arch masonry	12.70	" "	High.
Cortland cement concrete or Portland cemt rubble for abutments: Concrete	5.64	" "	Rather low.‡
Rubble	6.60	" "	Not used.
Nat. hydraulic cemt conc. or natural cement rubble haunching: Concrete	4.45	" "	Used.
Rubble	5.25	" "	Not used.

*Too low for work in bed of creek.
†Too low for light trimming in bed of creek.
‡Rather low considering cost of cement to contractor.
§Backing for second-class masonry.

is a bond stone making a bond of at least 1 ft. in the face of each wall. All face stones were cut at the quarry.

The table at the bottom of the preceding page shows the unit prices bid, Portland and natural cement being furnished the contractor at $2.50 and $1 per barrel, respectively, as stipulated in the contract.

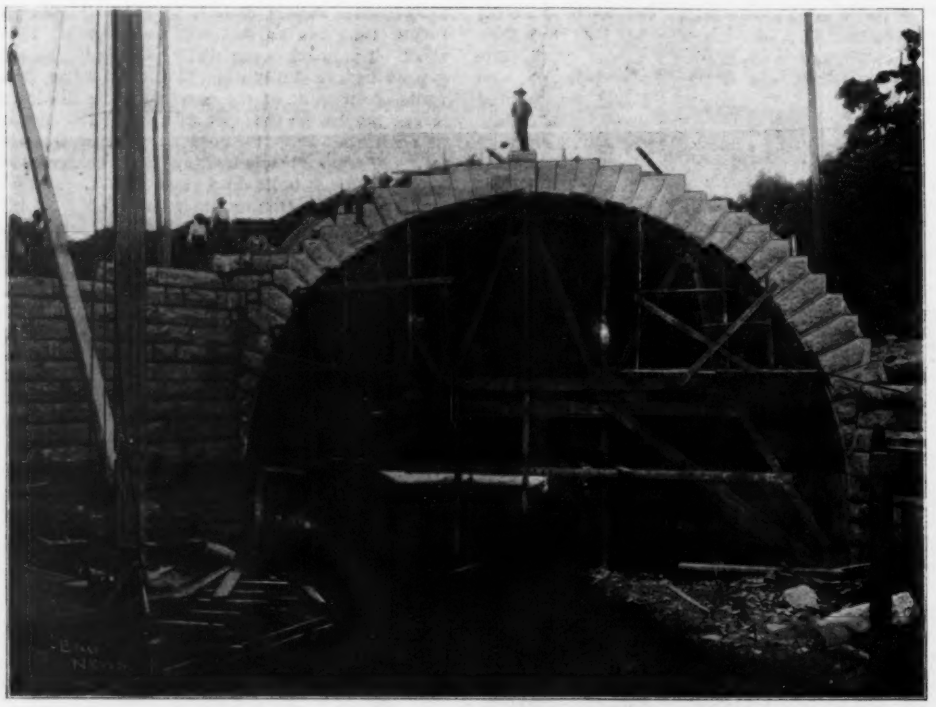

FIG. 4. END VIEW OF CULVERT SHOWING CENTER AND PORTAL MASONRY.

CENTERING.—The centering was designed by the contractors, subject to the approval of the Engineer Commissioner. It was built for one-half the length of the entire arch, with the idea of again using it for the second half by moving it ahead (Figs. 3, 4 and 5). When it was desired to build the second half of the arch the centers were struck in sections of about 20 ft. (the length of the lagging). There was no appreciable settlement of the arch when struck, although while building, the crown raised as much as ⅜-in., when the haunches were loaded, settling back to the original height upon the loading of the crown by the building of the brick arch complete. Other loading at the crown was not resorted to.

In order to move the centers ahead after striking, four additional A-frames (the lower frames of the centers upon which the trussed bowstring arches rest) were made and placed ahead of the centers in the direction in which the second half of the arch was to be built. Then the first four bows, reckoning from the end which was to be extended, with the lagging in place, were lowered by removing the wedges, so as to rest upon iron pipe rollers, which were placed upon two sets of 8 × 8-in. skids, which ran parallel to the barrel of the arch, and which rested upon the A-frames. These four arches with their lagging were pulled ahead by a rope fastened to them at either side of the center, the rope passing through blocks to the end of a derrick and thence to a hoisting engine, which furnished the necessary power. In the same manner the next four bow-frames were pulled ahead to the position just ocupied by the first four. This proceeding was carried on until the last four A-frames at the back were without any bow-frames resting upon them. At this stage the very last A-frame was pulled down to a horizontal position, flat on the bed of the creek, in which position, end on, it was pulled by means of the aforementioned block and tackle, along the bed of the creek, between the feet of the A-frames, which remained in their original position, to the front end of the centering. There it was erected in position. The other three detached A-frames were pulled into position and erected in the same manner. The bows were now ready to be pulled ahead again 20 ft., which, being executed, left again four A-frames free from bows resting upon them. These A-frames were moved ahead again and this operation continued until the whole center had been moved one-half the length of the arch.

The brick work was laid up in blocks. Six large blocks 11 ft. 8½ ins. each and five small ones 20 ins. each. In the small blocks the bricks were laid up as headers. In the large blocks the bricks were laid as stretchers in 9-in. concentric rings, and the adjacent rings were bonded wherever the continuity of the joints permitted. The back of the brick arch was kept as rough as possible in order to bond with the concrete backing. The fill has now been made to an elevation about 35 ft. above the crown of the arch, causing the crown of the arch to settle ⅜-in.

BRICK TESTS.—In connection with the inspection of the brick careful tests were made.

SAND TESTS.—The following tests were made upon concrete sand in order to show its weight per cubic foot with different percentages of water. In making the sand test, 4 cu. ft. of dry sand was first weighed, then 1½% of water by bulk was added and thoroughly mixed with the sand by turning over four times with shovels and raking it at the same time. Then the wet sand was weighed, and after weighing ½% more water was added, and the same operation repeated, as indicated in the tabulation, until 19% of water had been added. The weight of the dry sand was 93 lbs. per cu. ft. This weight per cubic foot decreased as the water was added, until 5% of water had been mixed with the sand, at which point it weighed 83.63 lbs. After this the weight per cubic foot increased until it reached its original dry weight of 93 lbs., which occurred when about 18% of water had been added.

No. test.	Water by bulk, %.	Weight, concrete-sand pr cu. ft., lbs.	No. test.	Water by bulk, %	Weight, concrete-sand pr cu. ft., lbs.
1.....	Dry.	93.0	11.....	7	83.94
2.....	1½	89.05	12.....	8	87.75
3.....	2	88.44	13.....	9	88.9
4.....	2½	87.35	14.....	11	88.75
5.....	3	86.85	15.....	13	89.25
6.....	3½	85.0	16.....	17	92.06
7.....	4	85.0	17.....	19	94.25
8.....	4½	84.65	18.....	23	96.75
9.....	5	83.63	19.....	29	99.50
10.....	6	83.81			

CONCRETE MAKING.—Considerable trouble was experienced in getting a uniform concrete mixture by using a continuous mixing machine where the contractor's force was not sufficient to handle the maximum output of the machine. If the velocity of the machine is not practically uniform the amount of water to be supplied to the mixture necessarily varies, making it difficult to get a uniform mixture. I am of the opinion that the force should be adequate to handle the maximum output of the machine, or the work stopped. In feeding the machine a very satisfactory arrangement was effected. The materials were deposited as indicated by the sketch, Fig. 6, the piles being kept constantly replenished during the day.

There were stationed at each pile of material as many men as there were shovels of material required per wheelbarrow. Five men were stationed at the stone pile, three at the gravel pile, two at the sand pile, and one at the cement box. The material was conveyed to the machine in wheelbarrows. The proportions were such that each shovel man put in only one shovel (or in the case of the cement, one scoop) of material. This practically filled a two-cubic-foot-wheelbarrow. The cement scoop was especially made according to the quantity demanded by the specifications, and was approximately 6 ins. in diameter and 7 ins. deep.

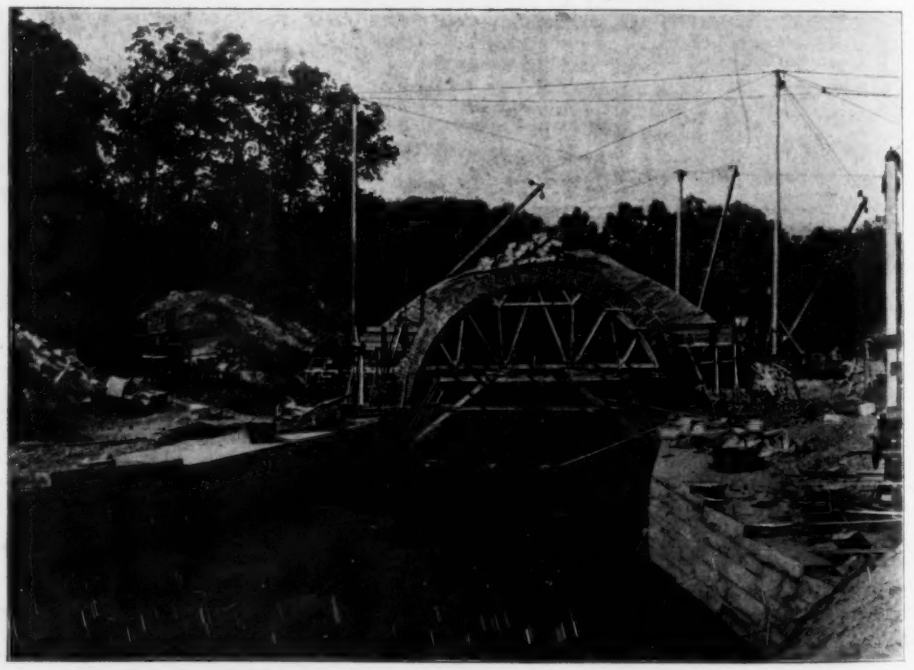

FIG. 5. VIEW SHOWING ARCH CENTER, BRICK ARCH AND CONCRETE ARCH BACKING.

DEPOSITING CONCRETE BY CHUTES.—It was stated in the specifications that concrete shall not be passed down to its place through a chute or thrown or dumped from a height, but must be carefully placed so as to retain the constituents evenly incorporated as mixed. I am of the opinion that the first part of the paragraph might

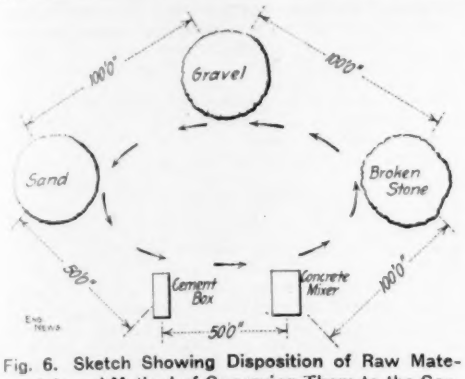

Fig. 6. Sketch Showing Disposition of Raw Materials and Method of Conveying Them to the Concrete Mixer.

properly be omitted. Concrete can be dumped a considerable distance without material injury to it if proper precautions be taken. On one piece of work under my supervision, in constructing foundation for a concrete viaduct, a vertical chute 15 ft. in length was used without any practical harm. The chute was of wood, 15 × 15 ins. square, with a canvas end. The concrete was dumped in batches of, say, 8 cu. ft., and the piles (of concrete) at the bottom of the chute were kept from coning by a man or two men, cutting down the top with hoes, thus largely reducing the tendency of the material to separate when it struck the pile. In another case, with a continuous mixer, a chute of sheet iron, semicircular in cross-section, about 2 ft. wide and 1 ft. deep, on a pitch of 45°, was constructed at the dumping end of the mixer and carried down to within a few feet of the bottom, where it dumped the conveyed concrete into wheelbarrows. The length of chutes was 15 ft. A lift-gate of sheet iron was arranged about 2 ft. from the end of the mixer, which held the material back until about a wheelbarrow of concrete had accumulated, at which time the gateman would open the gate and let the batch down the chute. A still more radical arrangement was inaugurated by the Cranford Paving Co. in the construction of Pier III. of the Connecticut avenue concrete viaduct. The concrete wass chuted about 60 vertical feet on a pitch of about 45°. A continuous mixer was used which fed into a sheet iron lined rectangular chute about 2 ft. 6 ins. wide × 1 ft. deep, with a gate about 2 ft. from the mixer, as described above. A wooden, sheet-iron lined hopper of pyramidal inverted box was placed at the bottom of the chute. This box was about 4 ft. 6 ins. deep, 3 ft. square in section at the top, and 1 ft. square at the bottom, and was placed on legs, so that its top was about 10 ft. above the ground or concrete upon which it rested. As the concrete work was carried up the hopper was raised and the chute cut off. In operating the apparatus the hopper was first filled, and when so filled the material was dumped from the bottom of the hopper by means of a gate regulated by hand, into wheelbarrows. The first two wheelbarrows in the morning and afternoon when operations were first begun were condemned on account of the separation of the ingredients. In operating the chute and hopper the work was so arranged that the hopper was kept full all the time. Care was taken to keep the horizontal joints between the abutting sheet-iron plates of the chute flush and the chute clean of set-up cement. The concrete was distributed over the pier by means of wheelbarrows. The accompanying view, Fig. 7, shows the apparatus.

In building the foundation for Pier II. of the same viaduct, the Cranford Paving Co. rigged up a much more elaborate apparatus, Fig. 8, with equally as effective results, which I think has been since patented by them. The concrete was conveyed horizontally from the mixer by a continuous rubber belt conveyor on double conical rollers. The width of the belt was 18 ins., and the length of the conveyor was 18 ft. The concrete was dumped at the end of the belt conveyor into a vertical iron chute about 12 ins. in diameter and 8 ft. long. This circular chute was fastened to the arm which carried the conveyor. The arm of the belt conveyor was supported by the ground at the mixing machine, and its other end was held by a rope fastened to a frame or bent, which rested upon the bottom of the foundation pit. It was the contractor's idea to have the dumping end of the conveyor lowered should it thus work more advantageously. The horizontal position was found most satisfactory.

Below the vertical chute, before referred to, and overlapping it about 6 ins., was a second slightly larger iron chute, working on the outside of the first one, and fastened by means of two ropes from the frame. This chute was raised by means of the ropes as the concrete was built up. The lower end of this adjustable chute was so arranged as always to be about 6 ins. below the top of the hopper, which was used for Pier III., and which is shown in the photograph. The above apparatus was operated as follows: The hopper and vertical chutes were kept practically full of concrete so that the concrete dropped only

Fig. 7. Chute Used in Depositing Concrete for Pier III., Connecticut Ave. Bridge, Washington, D. C.

about 3 ft. from the belt conveyor, and was gradually lowered as the concrete was drawn off in wheelbarrow loads through the gate at the bottom of the hopper. There was no apparent separation of the ingredients. I am of the opinion that the vertical drop with this apparatus could be as much as 100 ft. without serious injury to the mixture. The only point governing the practicable maximum height is that the time of the passage of the concrete from the mixer to the tail-gate should not exceed that of setting up.

RAMMING CONCRETE IN PLACE.—The use of as heavy a rammer as specified, 24 lbs., is not thought desirable, as it is too heavy for a man to handle eight hours, and unless dry concrete is used, which is not modern practice, it is too heavy. If a dry concrete is to be used and heavy ramming is necessary, I would suggest that the area of the base, as well as the weight, be specified. I have had very good results with a 17-lb. rammer with a base of 36 sq. ins. Paragraph 24 of the specifications reads:

> In the foundations, abutments, and backing, the layers shall be horizontal. If concrete is used in the haunching the layers shall be approximately normal or parallel to the back of the arch. Where the layers are parallel to the back of the arch, they shall be laid in longitudinal sections not exceeding 5 ft. in width, extending the entire length of the arch between face walls. These sections while being built shall be held in place by timber forms normal to the centering.

This specification was readily carried out as written, but the width of 5 ft. might properly, on an arch of this size, be changed to 15 to 20 ft. at the crown, where the layers are practically horizontal. Whether or not this method is preferable to horizontal layers I am unable to state.

A form should be built to the curve of the back of the concrete in that portion of the arch where the layers are normal to the arch, so as to give a surface to ram against. This gives better concrete on the top 6 ins. of the haunching and gives a smooth surface which can be readily plastered.

FROST DAMAGE.—The back of the haunching, which is of natural cement concrete, was not plastered. This concrete was exposed all last winter. It had not set up when the frost first came. All the top concrete which was exposed during the winter was seriously damaged to a depth of between 4 and 6 ins., and in one place over an area of 75 × 12 ft., to a depth of 10 ins. The natural cement was furnished the contractor by the District after the Standard tests. It, however, had not set up hard for two months after being placed.

I am of the opinion that from ½ to 1 in. of Portland cement mortar over this concrete would have prevented the injury to this concrete, which was due in part to the frost and to the hard rains which happened a few days after this work was completed. In several places the broken stones of the concrete were washed clean of cement to a depth of 6 ins.

GENERAL COMMENT.—The specification for first and second-class masonry, both of which were backed up with concrete or rubbie at a much lower unit price, stipulated that the contractor should be paid by the cubic yard in place. The amount of work to the engineer which this entailed has convinced me that the proper way to make a contract for stone bridge facing is by the superficial foot, or to a mean or neat depth.

The most important point in a specification for facing stone is to stipulate the maximum and minimum bed which will be allowed. The minimum bed is nearly always stated, but not the maximum. If the latter is not specified the contractor has the right to put in very large beds, thus largely increasing the cost of the work to the city by increasing the face work at the expense of the backing. This point, of course, applies particularly to a specification for work by the yard in place.

It is thought that the brick work and stone facing on this bridge are exceptionally good. In building the foundations for the bridge the contractors met with considerable underground water. Both foundations encountered an old timber dam which had been built upon rock and which caused them much expense in removing. The chief expense entailed by this dam, however, was the pumping of the water which followed along the old timbers, and ran into the foundations in great quantity.

During the building of the brick arch, after

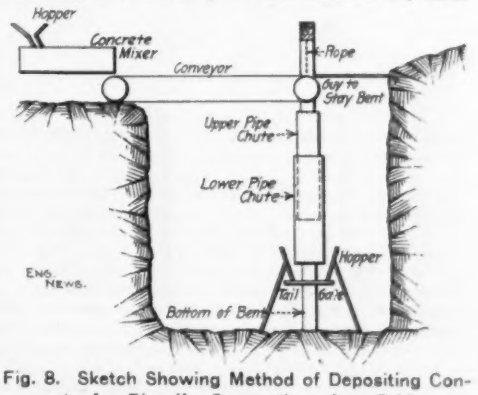

Fig. 8. Sketch Showing Method of Depositing Concrete for Pier II., Connecticut Ave. Bridge.

about 50 ft. of arch had been keyed, one of the inspectors informed me that the centering had lowered 1 in. I immediately inspected the centering and noted that the legs of the A-frames had buckled on an average of 3 ins., otherwise the centering was in excellent condition. The brick work at that time lacked about 8 ft. of being

keyed. I immediately ordered the work keyed with a single ring of brick, and also ordered timber struts to be cut and wedged into place between the faces of the two sides of the brick arch. I then measured the height of the lagging above the springing line of the arch and found no settlement, but a rise of ¼-in., which was to have been expected.

After consulting with the foreman who had charge of the construction of the center, I was informed that the buckling was due to the fact that a half-dozen A-frames were made too wide at the base, and had to be jacked into position, which caused the initial buckling.

I had overlooked this in my inspection of the center when built, with the result that it was with difficulty that the contractor was able to keep the bricklayers at work on centering which they believed unsafe. The bricklayers were hardly willing to accept the facts as proven by the correct measurement.

In construction of the brick arch considerable trouble was caused by the use of brick from different machines. The variance in their dimensions gave the bricklayers considerable trouble in holding the joints to ½-in. as specified. It is unfortunate that there cannot be maintained a standard size of brick.

The mortar used for the brick work was 1 to 3 Portland. This is a little too lean, and consequently too stiff, and I am of the opinion that 1:2½ or 1:2 would be economical in the long run. About 1,100 brick per bricklayer per diem were laid. Nine courses of brick forming the key were grouted, in single rings. In 50 ft. of the arch near the north facade sheets of tar paper were placed on the lagging to prevent the leakage of the grout. This procedure was fortunately abandoned on the remaining 162 ft. When the centering was struck the paper was removed by means of cold chisels at considerable expense to the contractor.

A NEW OIL TESTING MACHINE AND SOME OF ITS RESULTS.*

By Albert Kingsbury,† M. Am. Soc. M. E.

It has become well recognized by experimenters that there are two important properties of lubricating oils and greases on which their value depends—viscosity and body. Viscosity is the property by virtue of which the lubricants form comparatively thick films between rubbing surfaces, permitting perfect lubrication, a property which is well understood and capable of precise measurement. Thurston early pointed out the case of perfect lubrication as probably capable of exact mathematical treatment,‡ and Reynolds, in 1886, published an elaborate analysis of such a case,§ with application to the experiments of Beauchamp Tower.||

As a result of computations from Tower's data, Reynolds found that the minimum thickness of the oil film and the difference of the radii of the brass and the journal were .000375 and .00077 in. respectively, the load being 100 lbs. per sq. in. and the diameter of the journal 4 ins. In 1899 the writer experimented with a journal 3.82 ins. in diameter and 10 ins. long, bearings and journal having exactly the same radius. The chords of the bearing surfaces were 3 ins. each, the speed 80 and 190 revolutions per minute, and the journal was flooded with machinery oil. By measurement of the displacement of the bearings the oil film was found to have a mean thickness of from .00021 to .00023 in. under loads varying from 27 to 270 lbs. per sq. in.

A condition essential to the formation of such films, as shown by Reynolds, is that the rubbing surfaces should have a very slight inclination to each other in the direction of their relative motion. This condition is generally fulfilled by a slight difference in the radii of the journal and the bearing, due to the original looseness of fitting or to wear. When the loads are very great or the surfaces irregular, or when the conditions are otherwise such as to make the necessary inclination impossible, it is well known that the action of the lubricant is imperfect and frequently very defective. In such cases the theory of Reynolds, which so clearly accords with experiment for the conditions of perfect lubrication, becomes quite inapplicable; nor has any theory been formed which applies to these imperfect or extreme conditions. Such cases occur in pivots, where the surfaces are necessarily parallel, in cylindrical bearings which are too closely fitted, in any portion of any bearing surface where the pressure is unduly high, and in heavily loaded bearings generally. Under any of these circumstances the effect of the lubricant in reducing friction depends mainly upon the "body" or "oiliness." The nature of this property, or combination of properties, is not well understood, but it appears probable that it is an intensified viscosity in that part of the fluid within the region of attraction of the surface molecules of the metal.

One of the most frequent causes of contradictory results in friction tests is that the effects of viscosity may readily mask the effects of body, and another cause is found in the changes in the rubbing surfaces which always take place with wear, and which must, therefore, accompany any test for body.

In any well-fitted journal in which perfect lubrication exists, the friction is determined by the speed, the pressure and the viscosity of the oil. Varying any one of these factors while keeping the others constant, there is some value of the variable for which the coefficient of friction is a minimum* and which at the same time marks very nearly the limit of the variable for the condition of perfect lubrication. This is illustrated by the curves plotted in Fig. 2, representing tests made on the machine described later. In these tests the load and the speed were kept constant, the viscosity of the oil being varied in each case by varying the temperature. For each of the three oils, the minimum coefficient of friction is reached at a temperature of about 180° F., with the given speed and pressure. As the temperature varies either way from this value, the coefficient of friction increases; on the one hand increasing with the viscosity of the oil, the metallic surfaces being completely separated by a measurable thick film; on the other hand increasing because the decreased viscosity permits the surfaces to approach so that some parts of the nominal bearing areas are subjected to very intense pressures, up to the limits of strength or plasticity of the metals. It is in these localities that the body of the lubricant determines to some extent the friction and the wear of the journal, the viscosity being also effective on some parts of the area.

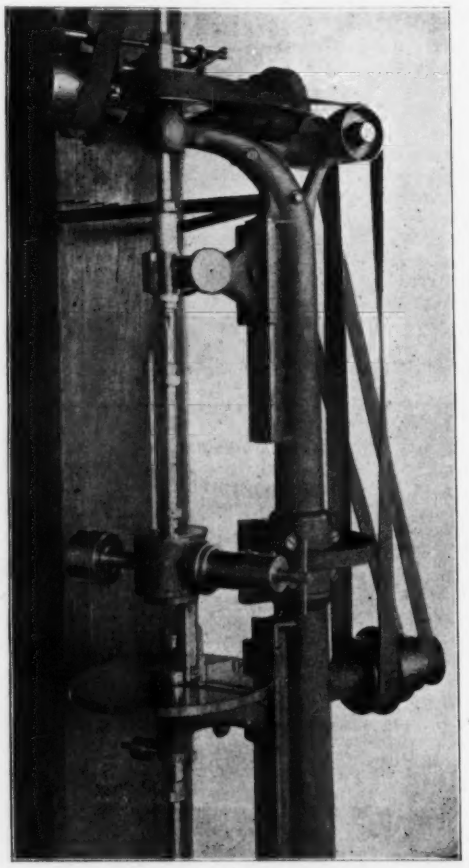

Fig. 1. A New Machine for Testing Lubricating Oils.

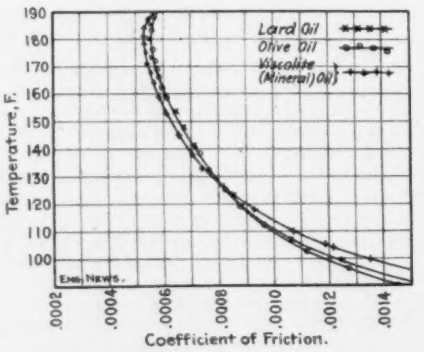

Fig. 2. Friction Tests of Oils.
Test journal, 1.37 × 2 ins.
Speed, 120 revs. = 43 ft. per min.
Pressure, 340 lbs. per sq. in.

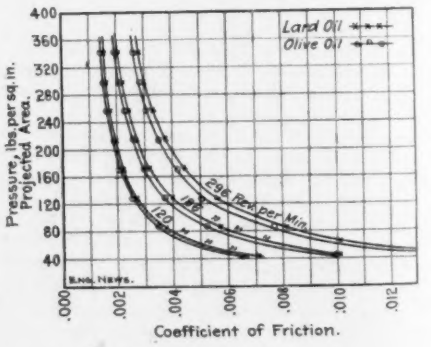

Fig. 3. Friction Tests of Oils.
Test journal, 1.37 × 2 ins.
Temperature, 90° F.

The relations of the coefficient of friction to the other variables, in a journal giving results as plotted in Fig. 2, may be stated as follows:

With increase of	Where the viscosity is effective, the coefficient of friction.	Where the body is effective, the coefficient of friction.
Pressure	Decreases.	Increases.
Speed	Increases.	Decreases.
Temperature	Decreases.	Increases.
Viscosity	Increases.	Decreases.
Body	.....	Decreases.

It is thus seen that the effects of body and of viscosity are in nearly all respects diametrically opposite, and that it must necessarily be very difficult to derive reliable information regarding the lubricating values of oils from friction tests in which the effects of viscosity and those of body are not separately recognizable. Under this consideration, methods of testing which are described in this paper are arranged with special reference to the conditions under which the effects of either property may be investigated independently of the effects of the other. The apparatus used is serviceable also for tests under any intermediate condition.

Fig. 1 shows the general appearance of the testing machine, for the frame and driving parts of which a 14-in. drilling machine was utilized. The test journal has its axis vertical; it is suspended from the spindle by means of a flexible coupling and runs between two opposed bearings in a cylindrical cup or case, which may be filled with the oil to be tested if a "bath" is desired. The load on the bearings is provided by means of a helical spring of 900 lbs. capacity, with screw adjustment and with a device for quick application or removal of the load without disturbing the adjustment. This spring is enclosed in a horizontal tube attached to the side of the oil case. The cup has a cover with a small hole for the insertion of a thermometer.

The cup and attached parts are borne on a hollow vertical spindle 1⅝ ins. in diameter, turning freely in a sleeve supported from the frame of the machine; the spindle extends about 2 ft. below the sleeve and is suspended from a fixed bracket by a tempered steel wire passing through the spindle to its lower end.* In testing, these suspended parts turn freely to a position where the torsion of the suspension wire balances the friction at the test journal, and the angle of torsion, which may be as great as 270°, is read from a graduated disk. The suspended parts being counterbalanced, there is no appreciable pressure of the spindle against its sleeve; and when the oil in this bearing becomes evenly distributed, there is no error from friction, as has been amply proven by tests with an "optical lever" as well as by the uniformity of the results in use. At the same time, the viscosity of the oil serves the purpose of damping the oscillations which arise from variations in speed or friction at the test journal. This mode of suspension gives large indications for very small frictions at the test journal, while a helical spring placed on the extension of the spindle is added for tests involving great friction.

The cup and the test journal contained in it may be heated as desired by a Bunsen flame. The revolutions of the journal are indicated by a counting device, not shown in the figure.

For tests involving perfect lubrication (friction due to viscosity only), the test journal used is 1⅝ ins. diameter, of tool steel, hardened, ground and polished. The brasses

*A paper read at the New York meeting of the American Society of Mechanical Engineers.

†Professor of Applied Mechanics, Worcester Polytechnic Institute, Worcester, Mass.

‡"Friction and Lost Work." Wiley & Sons.

§"Theory of Lubrication." Phil. Trans., 1886.

||Proceedings of the Inst. Mechanical Engineers, 1884.

*Thurston: "Friction and Lost Work," pp. 311, 325. Woodbury: "Measurement of the Friction of Lubricating Oils." Transactions Am. Soc. M. E., Vol. VI., p. 151.

are sectors cut from a ring finished in the lathe, each having an arc of about 120° and a length of 2 ins. These brasses are fitted with some care, so that when perfectly clean they may be made to adhere to the journal after the manner of well-fitted "surface plates." In making tests, care is taken to prevent wear of these parts, which are used only under such loads that the oil film effects complete separation of the surfaces and entirely prevents wear; the load is always relieved before starting or stopping the journal; and, finally, a friction device in the driving coupling safeguards the journal from motion

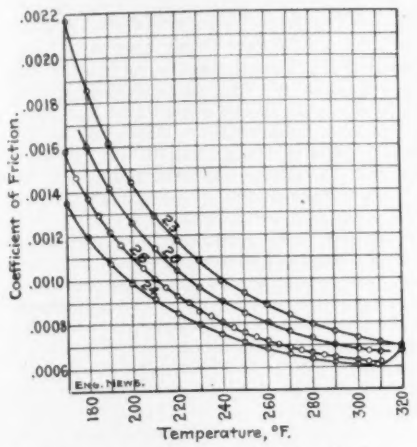

Fig. 4. Friction Tests of Cylinder Oils.
Pressure, 340 lbs. per sq. in.
Speed, 94 ft. per min.

against excessive friction. These precautions against wear are necessary to insure the constancy of results.

It will be noted that the above conditions are not such as occur in practice; but it should also be noted that this method of testing is intended to show the effects of viscosity in lubricants and not the varying imperfection of any particular bearing surfaces subjected to wear.

In Figs. 2 to 5 are shown curves plotted from tests made with the test journal and bearings just described, a bath of oil being used in each instance. Figs. 2, 4 and 5 show the effects of variation in viscosity upon the friction, both by the use of oils of different viscosities and by the variation in viscosity due to change of temperature. In Fig. 2, the lard oil and the olive oil have very nearly the same viscosity, the lard oil being slightly more viscous, as is also and more clearly shown in Fig. 3; the mineral oil (Fig. 2) is more viscous than either at low temperatures, but less at high temperatures (see also Fig. 6). Fig. 4 shows the frictions of four cylinder oils with varying temperatures; Fig. 5, four engine oils. Fig. 6 shows relations of friction, speed and viscosity for fine oils at three different speeds; the viscosity was found by the ordinary and rather crude pipette method. These curves, although relating to conditions not far removed from the limit of capacity of the journal, approximately verify Reynolds' deduction that the friction is proportional to the viscosity of the oil, and they also show the friction to vary roughly as the square root of the speed. The data for Fig. 6 were taken from average results of tests made in the laboratory of the Worcester Polytechnic Institute, by members of the class of 1901; the degree of certainty attained in the friction tests may be illustrated by the accompanying values of the coefficient of friction found by the successive experimenters, no corrections being made for variations in speed nor for errors in calibration of the torsion wire:

Coefficients of Friction for Sperm Oil; Pressure, 340 Lbs. Sq. In. 90° Fahr.

117 r. p. m.	182 r. p. m.	281 r. p. m.
.000906	.001171	.00146
.000915	.001158	.00155
.000886	.001158	.00151
.000915	.001125	

It may be noted that the lowest coefficients of friction shown in Figs. 2, 4 and 5 are extremely small, and the writer believes them to be smaller than any hitherto recorded for lubrication maintained solely by the motion of the journal. The minimum friction is but one-fifth of that of the best ball bearing, as far as tests of the latter have been recorded. The value for the minimum coefficient for all oils tested on this journal has been found to be approximately .0006, whatever the speed, pressure and temperature by which the minimum coefficient may be determined; the oils varying from "spindle" to "cylinder," the speeds from 42 to 101 ft. per minute, the pressures up to 340 lbs. per sq. in. and the temperatures up to 340° F. Very nearly the same minimum coefficient was found in the writer's test* of a journal lubricated by air only; the value in which case was .00075.

For tests for comparing oils with respect to body or oiliness, the best results have been obtained by the use of a hardened and polished steel journal ¼-in. in diameter, running between two brass bearings about 1 in. long; on this small journal pressures up to 8,000 lbs. per sq. in. may be applied if necessary. The samples of oil to be compared are contained in small brass cups placed inside the case and surrounding the test journal, each cup having a wire for transferring oil to the journal; the case, samples and journal are together heated to any desired temperature.

In testing for body the oils are compared in pairs, being applied alternately at the upper end of the bearing; one

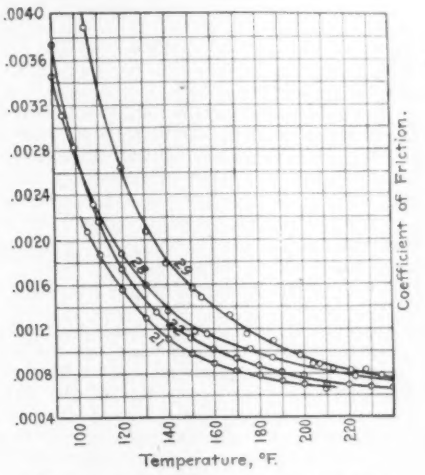

Fig. 5. Friction Tests of Engine Oils.
Pressure, 170 lbs. per sq. in.
Speed, 94 ft. per min.

being applied until the friction becomes constant or nearly so, the other is then applied until it displaces the first, and again the friction becomes constant at the new value; this process is repeated several times. The oil giving the less friction is assumed to have the greater body. In this way the order of the body values os six samples of oils of the same class may generally be determined for any given temperature in an hour or less; the friction indications rapidly follow the changes of the oils and are generally quite consistent. When the oils to be compared are of different classes (as mineral oils with fixed oils), the first friction indications on changing oils are frequently misleading, and a longer time is required to insure certainty of results.

The speeds for the body tests are made rather low and the pressures not unnecessarily high, in order to avoid heating and wear of the journal, since it is essential for comparative purposes that the surfaces should be in the same condition for both samples compared—a requisite which above all others led to the development of this method of testing. Again, the actual temperature of the

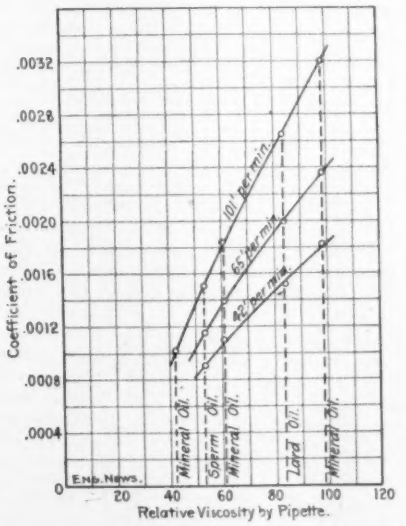

Fig. 6. Diagram Showing Relation Between Friction Viscosity and Speed for Five Different Oils.

oil at the test surfaces is shown more nearly by the thermometer if but little heating by friction be permitted. The writer has not found the order of body values, as determined by this method, to vary with the speed or the pressure within a considerable range. A speed of 50 to 100 revolutions (3 to 6 ft. per minute), with sufficient pressure to make the coefficient of friction only as great as .01 to .03, have been found most satisfactory; the pressures being from 500 to 5,000 lbs. per sq. in., according to the character of the oils.

The results of this method of testing for body agree thoroughly with the principal fact hitherto established with regard to body as distinguished from viscosity—namely, that the mineral oils as a class have much less body than the animal and vegetable oils. For example, in a body test of mineral oil and lard oil having viscosities 98.9 and 83.7 respectively at 90° F., as determined by the Dudley pipette, the lard oil, although the less viscous, gives very decided evidence of greater body, by its much smaller friction. On the other hand, certain cylinder oils, wholly or largely mineral, and exceeding lard oil greatly in viscosity have also greater body than lard oil.

The method of testing readily indicates differences in body in samples of nominally the same oil from different manufacturers, such as lard oil; change of body in a given fixed oil on exposure to the air for some time; the addition of small proportions of mineral oil to animal or to vegetable oil, or vice versa.

Among the specific results thus far obtained, the four cylinder oils whose variations of viscosity with temperature are shown in Fig. 4, were found to have body in the same order as viscosity; the body being tested at 180° and 312° F. Similar results were found for the oils in Fig. 5. Again, samples of castor, lard, olive, and sperm oils were placed in the order named by the body test, which order was the same as that of their viscosities. It thus appears that body is in some way related to viscosity, but the relation must be quite different in the mineral oils and the fixed oils.

The accompanying tables of observations will serve to show the character of the numerical results of tests made in this way, the oils compared being in the first case two samples of lard oil, and in the second case two engine oils, Nos. 28 and 29 (see Fig. 4 for viscosity tests); speed, 105 revolutions per minute (6.9 ft. per minute):

BODY TESTS OF WINTER STRAINED LARD OILS.

Oil No.	Torsion. Degrees.	Coefficient of Friction.	Temperature Fahr.
	Load, 300 lbs.; pressure, 2,550 lbs. sq. in.		
1	33	.0233	72
2	25	.0176	....
1	31	.0218	....
2	24	.0169	....
1	30.5	.0215	....
2	23.5	.0166	....
1	29.5	.0208	....
2	23	.0162	72

BODY TESTS OF ENGINE OILS.

Oil No.	Torsion. Degrees.	Coefficient of Friction.	Temperature Fahr.
	Load, 200 lbs.; pressure, 1,700 lbs. sq. in.		
29	11.5	.0124	69
28	15	.0161	69
29	11	.0118	69
28	15	.0161	69
	Load, 100 lbs.; pressure, 850 lbs. sq. in.		
28	8.5	.0182	120
29	4.0	.0086	120
28	5.0	.0107	120
29	3.5	.0075	120

Thus, while the coefficient of friction is not always constant for any one oil, the one effecting the greater reduction of friction is readily distinguished, and, hence, is to be regarded as having the greater body. This appears to be the principal use which can be made of the numerical results, since the mean values of the coefficients of friction are not characteristic of the oils, but depend also upon the varying degree of roughness of the surfaces, the loads, the speeds, the temperatures, and the kinds of metal forming the journal and the bearing. Nevertheless, great or small differences in the values of the coefficients of friction must be taken as indicating correspondingly great or small differences in body.

THE WIDENING OF LONDON BRIDGE is being carried out under the direction of Mr. E. Cruttwell, M. Inst. C. E. The present London Bridge was designed by Rennie and opened to traffic in 1831. It had iron arches, carrying a 34½-ft. roadway and two 9½-ft. sidewalks. The widening is being done by building out granite brackets, or corbels, from the piers, and the arches will be rebuilt in steel, permitting a 37-ft. roadway and two footways each 14 ft. wide. During construction foot passengers are carried on two temporary truss bridges, which also support the traveling cranes for the builders. As falseworks are not permitted in the river the new spans are erected on pontoons and floated into place.

A TRACK-BREAKING MACHINE is used by the St. Louis & Suburban Ry. for tearing up old street railway tracks. The machine resembles a box car, with two heavy iron arms projecting in front and extending toward the ground. A heavy chain along each arm passes over a sheave at the end, and has strong hooks by which the chain is atached to the rail. When the chains are hauled in by the winding engine on the car, the track is torn up bodily, ties and paving being so loosened that they are easily removed. The machine has greatly facilitated the work of tearing up old cable railway tracks embedded in concrete, as without it the breaking up of the concrete by picks and sledges would have been very tedious. Where these tracks have been torn up, cross trenches are roughly made for wooden ties, leaving the large mass of old undisturbed concrete between. Heavy girder rails are spiked to the ties, lined up by means of a transit, and concrete is then rammed in around the ties and old concrete to form an even and solid bed for new paving.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

It is not so many years ago since the ordinary procedure, when a railway corporation proposed to build an extension to obtain entrance to a city, was to find what inducements the city would offer to obtain the line. It has been common practice for cities to grant free rights of way through streets, exemption from taxation, and often free depot grounds as well. Besides this, many cities and towns in the days of real estate booms subscribed heavily to railway stock or bonds or gave an outright cash subsidy to secure a new line. There are hundreds of American cities and towns to-day paying interest on large burdens of debt incurred in aid of railway enterprises.

A remarkable contrast to this is the contract which has just been closed between the Pennsylvania Railroad and New York city, under which the former is to build tunnels under the North and East Rivers, and a great underground station on Manhattan Island. These lines are to be wholly underground, and at a depth so great that there will be no interference with the city's own system of local rapid transit railways. The space utilized therefore is space which the city does not and cannot use itself; and the railway company, in order to make use of it, has to invest an enormous sum of money in the construction of a system of submarine tunnels which promises to be one of the most difficult and hazardous pieces of engineering work ever undertaken. Notwithstanding this, the railway company is to pay the city as annual rental for the space occupied by its tunnels 50 cts. per linear foot of railway track for ten years after completion and $1 per ft. for the next 15 years. For the use of the underground space beneath streets a rental will be paid of $15,140 a year for ten years and double that amount for the ensuing 15 years. For the street space occupied at the terminal station the charge will be $36,000 a year.

Besides this, the company has had to purchase a great amount of real estate at the site of its terminal and along the lines of the tunnels at an expense estimated at some $10,000,000. On all this real estate and on the entire value of its property within the city limits the railway will have to pay taxes which are roughly estimated at $500,000 per annum. Furthermore, while the company receives from the city a perpetual franchise, it is provided that a reajustment of the payments by the company to the city may be made at the end of 25 years.

Authorities on economics have long agreed that municipalities ought to control not only their means of internal transportation—street railway lines—but their terminals for street railway lines. Until very recently, however, this principle has been wholly ignored in American cities. The Pennsylvania franchise is most notable for its recognition of this principle, as well as of the other principle that payments should be made to municipalities for the grant of franchises.

It may seem strange that, notwithstanding this, the Pennsylvania franchise has been held up for many months awaiting the approval of various municipal officials, of whom the Board of Aldermen were "last, but not least." As announced in our last issue, the franchise finally passed the Board of Aldermen on Dec. 16 by a vote of 41 to 36. The chief ground on which its passage was contested before the Aldermen was not that the city's interests were not fully protected, but that labor's interests ought to be protected by the insertion of clauses compelling the company to pay the "prevailing rate of wages," and to enforce the eight-hour day in the construction of its new tunnels and terminals. In defense of this idea a prominent labor leader was quoted as saying that no right-minded man would require a man to work in the darkness and dangers of a tunnel under the river for more than eight hours a day. This seems on its face like a plausible argument; but a little more knowledge of actual practice in tunneling work under compressed air rather takes the edge off it. In all probability the tunnels will be driven under very heavy air pressure, and it is customary and necessary under such conditions to work the men shorter hours than any labor union has ever proposed. Shifts of four hours, three hours, and even two hours, have been used in compressed air work, and that without compulsion from legislative enactment or dictation by a labor union. The probabilities are, therefore, that the laborers on the Pennsylvania tunnel will work no longer hours in the hole under the river than they would have done had the 8-hour clause been tacked on to the franchise.

A good illustration of the present activity in car and locomotive construction and in the railway business generally is furnished by a table in the "Proceedings of the American Railway Association," just issued, showing the number of cars and locomotives under construction on Jan. 1 and on July 1 for the past four years. It should be said that the table accompanies the report of the Association's Committee on Railway Safety Appliances, and its chief purpose is to show the progress in the application of power brakes to cars and locomotives. The showing made of the activity of car and locomotive construction is merely incidental. We take the figures from the table as follows:

Date.	Under contract or Construction. Freight cars.	Locomotives.
Jan. 1, 1898	14,717	217
July 1, 1898	33,088	302
Jan. 1, 1899	32,614	440
July 1, 1899	35,684	519
Jan. 1, 1900	102,485	1,192
July 1, 1900	30,606	1,001
Jan. 1, 1901	54,118	1,102
July 1, 1901	52,823	1,311
Jan. 1, 1902	77,225	2,081
July 1, 1902	91,095	2,172

It is of interest to note also that the total freight cars in service increased from 1,110,045 on Jan. 1, 1898, to 1,488,197 on July 1, 1902, and the locomotives in service from 32,771 to 37,945. This is an increase of 377,152 freight cars and 5,174 locomotives during the four and one-half years which the statistics cover. A better illustration of the enormous expansion of the railway business during the past few years could scarcely be given.

A still better idea is obtained, however, when it is remembered that notwithstanding this large increase in rolling stock, there has probably not been a time for many years when railways have been so short of cars and of motive power as during the past six months. Of course, some part of the car famine has been due to the tying up of cars on yard tracks, which suggests the idea that increase in capacity of yards and terminals had not kept pace with the increase in cars.

Turning to the primary purpose of the table, it is of interest to note that whereas on Jan. 1 1898, only 41.4% of the freight cars in service were fitted with air brakes, on July 1 last no less than 77.8% were so fitted. There has been an actual decrease in the freight cars in service not fitted with air brakes amounting to 320,000 in the past 4½ years. Of locomotives in service only 282 are reported without power-brake equipment, whereas there were 2,944 on Jan. 1, 1898.

These figures are of particular interest in connection with the report of the Interstate Commerce Commission just issued, in which a recommendation is made for further legislation in connection with air-brake equipment. It is urged that trains shall be required by law to have at least 50% of the cars equipped with power brakes in operative condition. In view of the rapid progress which is being made in the application of brakes and the rate at which the old cars without brakes are disappearing from service, we fail to see the necessity for additional legislation of this sort. The fact is that there are only about 300,000 freight cars still running without air brakes, or, as shown above, only about one-fifth of the total in service. These are practically all old cars, most of them very old. The great majority of them are of small capacity. As shown above, they have been either disappearing from service or else receiving brake equipment at the rate of 70,000 a year for the past five years. A large proportion of them would now be discarded except for the pressure of traffic upon the railways and the consequent demand for cars. With the first lull in business these cars will be left on side tracks or sent to the scrap heap, because the business can be more economically handled in the newer cars of greater capacity.

Commenting on the advance in railway freight rates in our issue of Dec. 11, we said that the railway should be considered as a monopoly in determining the rates which it is fairly entitled to charge. A great part of the troubles and difficulties which have been experienced in attempts at government supervision of railways have been due to the attempt to treat the railways as competitive industries, and to keep railway competition alive by process of law. Many states have embodied a prohibition of the consolidation of competing railway corporations in their constitutions; but consolidation has gone forward just the same.

In the annual report of the Interstate Commerce Commission the situation is summed up as follows:

> The tendency to combine continues to be the most significant feature of railway development. It is not open to question that the competition between railroad carriers which formerly prevailed has been largely suppressed, or at least brought to the condition of effective restraint. The progress of consolidation, in one form or another, will at no distant day confine this competition within narrow and unimportant limits, because the control of most railway properties will be merged in a few individuals whose common interests impel them to act in concert. The resulting situation involves consequences to the public which claim the most serious attention. A law which might have answered the purpose when competition was relied upon to secure reasonable rates is demonstrably inadequate when that competition is displaced by the most far-reaching and powerful combinations.

The arguments against the metric system and its proposed compulsory use in Government work which were made at the recent meeting of the American Society of Mechanical Engineers appear to have excited the ire of our esteemed contemporary "The Electrical World and Engineer." In its issue of Dec. 13, it says that the society has "passed under the fanatical domination of the rule-of-thumb contingent," and it then bestows

upon the misguided members who opposed the metric system a choice collection of names, from which we select a few examples as follows:

"Conservative enragés."
"Old fogies."
"Back numbers."
"Superannuated fanatics."
"Hide-bound fanatics."

It further proceeds to accuse the gentlemen designated in the above select terms, of "senile fanaticism," "general imbecility," "wilful and deplorable ignorance," and "frenzied ravings."

We venture to express mild doubt whether our esteemed contemporary's argument couched in the above language will convert any opponent of the metric system, or eliminate any of the difficulties which have been shown to stand in the way of its adoption. If the electrical engineers engaged in naval work find the metric system more convenient for their calculations, there is nothing in the world to prevent their using it; but why they should move Heaven and earth for legislation to compel the naval architects and the steam engineers to use the same system upon the hulls and machinery of Government vessels is something which passes comprehension.

Apropos of the use of the metric system in place of the existing units, it has been acknowledged by its advocates that one of the great difficulties is in learning to think in the new system. A correspondent who has evidently read the article in our contemporary above referred to, sends us the following communication:

Sir: A metric friend of mine, who believes that no one but a superannuated fanatic would be guilty of using any other than the metric system of weights and measures, wishes to put a steam heating system in his house, and asks if I will check up his calculations, which are given below.

The house is built on a corner lot, 7.620 × 30.48 meters, and its cubic contents are 1132.7 cubic meters. Empirical rules given in engineers' reference books, when translated out of their fossilized English terms into the more convenient metric terms, give the following rules for heating a building to 21° C. when the outside temperature is — 18° C., the steam being at 100° C.:

9.29 sq. decimeters of boiler heating surface will supply 14.16 cu. meters of cubic contents of the building; or 0.743 sq. meters of radiating surface, or 7.31 meters of pipe 25.4 millimeters in diameter.

9.29 sq. decimeters of radiating surface will emit 70 kilogram-calories per hour when the room is at 21° C.

0.45 kilogram of coal will transmit 2,500 kilogram-calories into the steam.

The grate surface should be so proportioned that not over 2.27 kilograms of coal will be burned per hour for each 9.29 sq. decimeters of grate.

These rules give the following:

Boiler heating surface required, 1,132.7 cu. m. ÷ (14.16 ÷ 9.29) = 743 sq. decimeters, = 7.43 sq. meters;
Radiating surface, 743 sq. decimeters, × 0.743 ÷ 9.29 = 59.44 sq. meters;
Lineal meters of 25.4 mm. pipe, 743 × 7.31 ÷ 9.29 = 585.2 meters;
Heat radiated, 5,944 ÷ 9.25 × 70 = 44,800 kil-calories per hour;
Coal burned per hour, 44,800 ÷ 2,500 × 0.45 = 8.06 kilograms;
Grate surface, 8.06 ÷ 2.27 × 9.29 = 33 sq. decimeters.

Will you kindly advise me how to answer my metric friend? It will not do to use any of his picturesque English (not metric) expressions, such as "futile rancor" and "imbecility," for he tells me he stands 1.87 meters in his stockings, has a girth around the chest of 1.18 meters, and weighs 90 kilogrammes!

Hide-bound.

Instead of answering our correspondent directly, we may suggest that this is a fair example of the form in which, to comply with the letter of the proposed law, calculations would have to be made for heating, let us say, an officer's house at a military post, or a navy yard.

AN HONEST AND EFFICIENT ADMINISTRATION FOR NEW YORK CANAL CONSTRUCTION.

The question what New York is to do toward canal improvement is to be one of the most prominent at the approaching session of the New York legislature. At the present time the chances seem favorable that some action will be taken by the legislature looking to the construction of a large barge canal from the Hudson to the Lakes. Any such action, however, will require approval by a popular vote to make it finally effective.

With these facts in mind, we desire to call the particular attention of all those interested in the New York canal problem to the paper in this issue of Engineering News entitled "The Reorganization Needed in New York Before Canal Construction." The author of this article has held a responsible position in connection with New York canal work in the past, and speaks with an intimate knowledge of actual conditions. He is wholly without political or local bias, and in fact is now engaged in engineering work in another state. His statements are entitled to the most careful consideration by those interested in the proposal to build a barge canal. Furthermore, we can testify from numerous other unbiased sources of information that the warning which he gives is couched in terms none too strong. If the present canal organization is entrusted with the task of expending $50,000,000, the well-remembered $9,000,000 fiasco will be a mere trifle in comparison with the resulting disaster.

In saying this, moreover, we are not criticising men or parties, but methods. In fact, the most fair-minded and best-informed judges agree that it was methods rather than men which was chiefly responsible for the $9,000,000 scandal. Like causes produce like results. Until methods are changed it will be absurd to ask the people of New York to appropriate some $50,000,000 to $80,000,000 to be expended under the same methods which were tried and found so lamentably wanting in 1895.

But, it may be said, what should be put in place of the present system? To this question, the author of the article pays comparatively little attention, devoting his chief effort to making plain the evils of the present canal administration. At the close, however, he suggests that the State could copy to advantage the experience of New York city with its successful Rapid Transit Commission. It is this suggestion which we desire to take up and urge with every emphasis possible.

If New York taxpayers are to spend a vast sum of money for the construction of a barge canal, they want that money expended economically and efficiently. Business and not politics must govern the work throughout. Moreover, unless the voters of the State believe that their $50,000,000 or $80,000,000 for a canal is to be actually spent for a canal, and not to build up a political machine, or to line the pockets of political leaders, they will bury the appropriation under such an adverse majority that the canal scheme will never be heard of again.

Now how can the legislature assure the voters that the money they are asked to give will be honestly and economically used? They can do so by cutting loose entirely from the present clumsy, complicated, and fatally defective system of carrying out canal works and placing the entire work of constructing the canal in the hands of a non-partisan engineering commission.

The fact is that during the past twenty years the commission plan for constructing great public works has been adopted in connection with nearly every engineering work of magnitude, and it has been an entire and unqualified success. We may cite for examples such works as the Chicago Drainage Canal, the Boston Subway, the New York Rapid Transit Railway, the Metropolitan Sewerage System in Massachusetts, the New Orleans Drainage System, and for the largest and most notable example, although the work has not yet been undertaken, the Isthmian Canal.

In all these public works and in many others of smaller magnitude in all parts of the United States which have been carried out in a similar way, the work has been done with complete honesty, efficiency and economy. Of course, there is a possibility of making a commission an adjunct of a political machine, and in some isolated instances the commission plan has failed because of this; but where a commission has been made up of men of reputation and ability, success has been invariable.

If, then, the New York authorities decide to adopt the barge canal project at the coming session of the legislature, they should couple with their favorable action such legislation as will place the entire conduct of the work in the hands of a non-partisan commission. In forming such a commission, as in the case of the Isthmian Canal Commission, the foremost place should be given to engineers, since they are best competent to handle the administrative problems involved.

We are well aware that political precedents on the New York State Canal works are all against any such radical innovation. It was even attempted to defend the $9,000,000 canal work on the plea that no more was wasted and stolen than had been the rule in previous canal enlargements. Not impossibly, some of the interests which are now working for a barge canal appropriation may grow lukewarm if the opportunity for political plunder is cut off. We counsel the commercial bodies of the State to pay no heed to those who may threaten to oppose the canal project if the work is to be turned over to a commission. It must not be forgotten that the voters of the State have to sit in final judgment upon any favorable action which the legislature may take; and if the business men in the legislature yield to the politicians, the voters will interpose an effective veto to the whole measure. "Better no canal at all than another $9,000,000 scandal multiplied a half-dozen times over" will surely be the judgment of the voters.

LETTERS TO THE EDITOR.

The Drainage in Irrigated Towns.

Sir: In several cities and towns in the semi-arid states basements are filled with seep water during the irrigation season, and the health of the residents is seriously menaced.

Tile drainage has been proposed. Many citizens oppose it because expensive, and claim it has been tried in places and proven a failure. They even cite the names of places, from some of which a denial has come of attempt and of failure.

Can any of your readers give facts about cities and towns anywhere in the world where tile drainage has proven efficacious? Yours truly, Citizen.

For the Metric System.

Sir: Regarding standards of measures and weights, some better information is due to the authors of both articles in your last issue.

How can the author make the imputation of ignorance to civil engineers regarding the necessity of naming standard articles according to their true dimensions, and not know that in his instance of a small metal pipe, leading firms manufacture pipes as follows:

		Ins.		Ins.
Nominal diameter,		¼;	internal diameter,	0.27
"	"	⅜;	" "	0.364
"	"	10;	" "	10.019, etc.

and all this without any remarkable trouble to the users of such articles.

Against the pretension that the metric system gives any trouble in European and South American countries, I feel obliged to testify in the name of truth that during many years of practice there in various branches of civil and mechanical engineering, I never heard, read or experienced anything of the sort.

I firmly believe that all sincere people with work to perform before them, who really have to deal with measures and weights, and who have practical experience with different systems of measures and weights, will recommend the decimal system. Neither the keeper of a store with various standard articles nor the mechanic who works at their manufacture have anything to do with these questions. Surveyors, computers, architects, engineers and builders are actually using some makeshift of a decimal system, which proves the inherent value of the same for the creative professions.

If brought to the test I believe the voters of this country would recognize the most enlightened road to open for their descendants, just as other nations have done. To believe, however, that this would necessarily cause the change of all standard articles is as erroneous as to believe that the first leaders of this nation would have benefited their cause by throwing away their wigs, when they relinquished the foreign yoke. These wigs have disappeared in time, without giving much to think or talk about. Very respectfully, C. S.

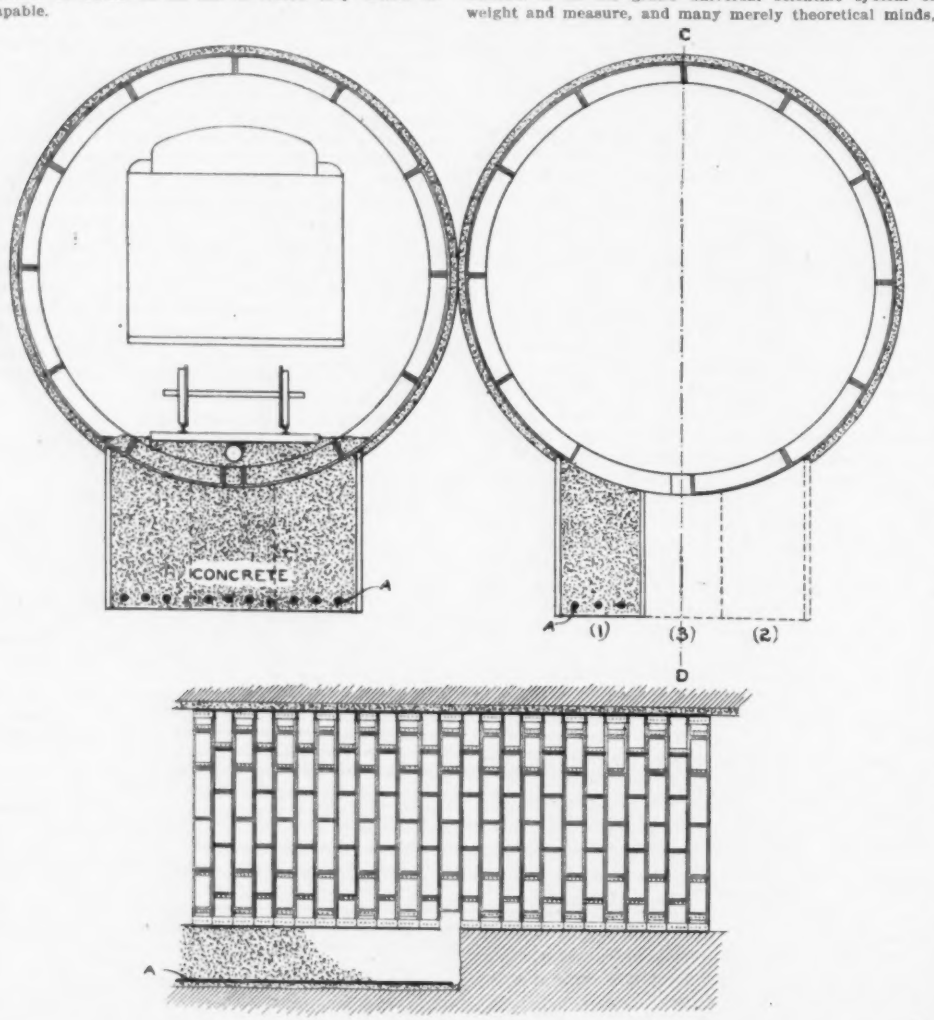
Washington, D. C., Dec. 15, 1902.

Against the Metric System.

Sir: "ABSURD!" Yes, that is the word with which the committee of the American Society of Mechanical Engineers on the metric system fitly characterized and contemptuously dismissed the bill now before Congress, making our own system of linear measurement illegal. That word was the necessary conclusion from the facts presented in the report of the committee.

The promoters of this measure were very properly excused on the ground of ignorance. If they had the least idea of what they were doing, of the unapproachable ex-

cellence of the system of linear measurement on which they were laying their hands, an excellence which is briefly outlined in the report of the committee, but which can be realized only by those who are familiar with its use, their advocacy of this bill would be without excuse, or rather it would be an act of which they would be incapable.



LONGITUDINAL SECTION C-D.

FIG. 1. DESIGN FOR NORTH RIVER TUNNEL WITH CONCRETE-STEEL FOUNDATION.
Proposed by Jesse W. Reno, E. M.

To begin with, I arraign the metric system itself as absurd. First, its pretension to be scientific is absurd. The idea on which this system was founded was big and childish; one which no people except the French could ever have thought of. To them it seemed sublime. They would take for a unit 1-10,000,000 of a quadrant of the

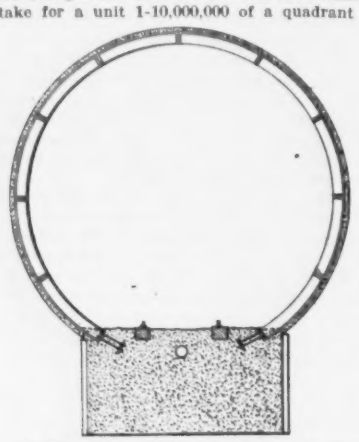


Fig. 2. Modification of Fig. 1, with Lower Segments of Lining Omitted.

meridian, or the distance on the earth's surface from the equator to the pole, and make this the unit of a grand decimal system of measurement of everything on the earth and in the heavens, and from this they would derive a unit for another grand universal decimal system of weight.

After the meter had been materialized in a metal bar, and this bar had been legally proclaimed to the world as the said universal unit, it was found to be too short; and the absurdity of this visionary fantasy stood exposed. The meter is merely an arbitrary unit, as any unit of measure or weight must necessarily be.

This performance would be too ridiculous to notice were it not for these two facts. The metric system is still proclaimed to be the grand universal scientific system of weight and measure, and many merely theoretical minds, and I am sorry to say some practical mechanical minds also, in this country are dazzled by its brilliant pretensions. The fantastic foundation is also a key to the character of the system. We shall see that as a whole it is the product of the same merely theoretical and visionary minds.

Secondly, the metric system is absurd in confounding together weights and measures, things which are entirely dissimilar and unrelated, and applying the same system of division to both. Universality was the hobby and the blunder of its schemers. Thus we have this result. Physicists deal with minute quantities, and do not measure, but only weigh. In the free exercise of their right to choice they found the gram and its decimal divisions to be admirably adapted to their use; their work lying within the natural field of the decimal system. From this they jumped to the universal conclusion, which is not merely unscientific, but is senseless, that the metric system must be equally suited to everything, to things large as well as small, and to measurement as well as to weight. But English-speaking people who measure do not agree with them. Therefore, these people must be deprived of their right of choice, and compelled by law to take the medicine that these doctors think will be good for them. This illustrates a radical absurdity of the metric system, applying one universal method to everything.

Confining our attention now to measurement, with which mechanical engineers are chiefly concerned, I note, thirdly, that the metric system is absurd in ordaining a single unit of measurement for everything, from the least to the greatest, when all other systems employ a number of units, each one especially adapted to a larger or a smaller field. This absurdity stands confessed. The metricists found themselves after all compelled to employ three units, the additional ones being the Kilometer for land measures, and the Millimeter for mechanical measures, thus making necessary the use of three decimal points.

Fourthly, the metric system is absurd in forbidding the use of division by continual bisection, the natural method which first occurs to everybody, and which possesses important advantages, as mentioned in the report of the committee; thus interfering with individual freedom of choice, which is a natural right, and ordaining for universal use the decimal system of division only, the proper field of which is in the expression of very small or fractional quantities, and which is wholly unsuited to express large dimensions.

This absurdity is realized in its most aggravated form in mechanical measurements, in which every dimension, however large, it was found necessary in the metric system to express in millimeters, the smallest unit, .03937007 of an inch. Thus, 38 ft. are 11,558 mm., and these five figures and two letters must be written. Nice to remember! We might just as well be compelled to express all divisions of the circle or of time in seconds.

But, say the metricists, we want uniformity. Well, in the English system of linear measurement we *have* uniformity. It presents the very ideal of uniformity. Throughout the United States and the British empire, all English-speaking people on the globe, in their great variety of occupations, every man who measures anything for any purpose, all employ the same identical system of measurement. Its great practical excellence has compelled its universal adoption by men free to use the metric or any other system if they want to, and with the same freedom of choice this excellence will make its use universal.

The proposed law excepts land measurement. The same reasons should cause all measurement to be excepted from it. Yea, they are tenfold stronger in the case of mechanical measurement. It would produce quite as great confusion, or chaos, in mechanical as in land measurements, indeed far greater. Its disastrous effects in cutting us off from our mechanical past, and in annihilating our standards and our literature would be inconceivable, and all for what? Echo answers, What?

A judicious law, giving to this nation the same uniformity of weights that we now enjoy of measures of length, would doubtless be hailed as a benefit. Adherence to the proposed law, applying the metric system, which confounds measures and weights, and applies one arbitrary system to both, will bring our legislators, sooner or later, to realize that our system of linear measurement is interwoven with the life of this people; that they realize its inestimable value, and that they are fully able to maintain it.

Chas. T. Porter.

Montclair, N. J., Dec. 16, 1902.

Smoley's Tables; Some Convenient Methods of Calculation by Their Use.

Sir: Having had occasion recently to calculate the weights of several prismoidal figures, whose dimensions were expressed in feet, inches and fractions of an inch, I found that the use of "Smoley's Tables" greatly facilitated the work. Thinking that the method might be of interest to many readers of Engineering News, I hereby submit it.

In Smoley's tables we have the logarithms and squares (the latter given in feet and decimals of a foot) of quantities expressed in feet, inches and fractions of an inch, varying by thirty-seconds of an inch. To use these tables in calculating the weight of a prismoidal figure, let the

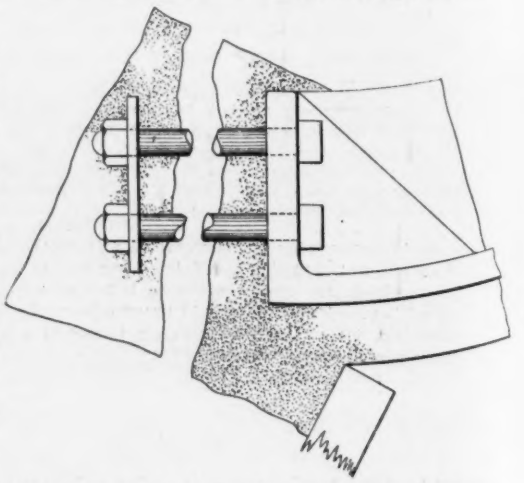


Fig. 3. Detail of Connection of Segments to Concrete Base.

weight of the prism be called x^3, the three dimensions of the prism, a, b and c, and let H equal the weight of a cubic foot of the substance.

Then the required weight is equal to

$$x^3 = a\,b\,c\,H,$$

and

$$\log a + \log b + \log c + \log H = 2 \log x;$$

or,

$$\tfrac{1}{2}\,(\log a + \log b + \log c + \log H) = \log x. \quad (1)$$

Since the tables give the second power of the root paral-

lel with its logarithm, we can read x^2 direct from its logarithm, which is the weight sought.

Example: Required the weight of a cast-iron figure of dimensions:

a = 1 ft. $1^{13}/_{32}$ ins.; b = 2 ft. $6^{25}/_{32}$ ins.;
c = 1 ft. $10^{3}/_{4}$ ins., and H = 450.

From Smoley's tables we find,

log 1 ft.	$1^{13}/_{32}$ ins.	= 0.04813
log 2 "	$6^{25}/_{32}$ "	= 0.40911
log 1 "	$10^{3}/_{4}$ "	= 0.27780
log 450		= 2.65321
		2 | 3.38825
		1.694125

Then in Smoley's tables we get the square corresponding to this logarithm as 2,444.83, which equals the desired weight of the figure.

Naturally, this method of solution may be adapted to a number of other uses, in which we may be either seeking x^2 directly or may let x^2 equal the unknown quantity of our expressions.

Thus, if we let x^2 equal the area of a plate whose dimensions are a and b, we have

$$\tfrac{1}{2} (\log a + \log b) = \log x.$$

We may use equation (1) directly for the calculations of masonry or earth work by putting H for the number of cubic feet in a cord or cubic yard, as the case may be. In these calculations, as H is a divisor the equation, of course, becomes

$$\tfrac{1}{2} (\log a + \log b + \log c - \log H) = \log x.$$

In the foregoing examples we have taken advantage of the novel arrangement of the tables whereby we read the square directly from the known logarithm of its root. In the following example we make use of the reversal of this principle by obtaining the logarithm of the root from the given square.

Example: To find the ordinate of an ellipse having semi-axes a = 8 ft. $7^{11}/_{16}$ ins., and b = 6 ft. $2^{7}/_{8}$ ins., for the abscissa x = 5 ft. $6^{1}/_{4}$ ins.

From the equation of the ellipse:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1;$$

we get,

$$y = \frac{b}{a} \sqrt{a^2 - x^2}.$$

Hence,

$$\log y = \log b + \log \sqrt{a^2 - x^2} - \log a.$$

From the tables find the logarithm and square of a, the square of x and the logarithm of b; subtract x^2 from a^2, get the logarithm corresponding to this difference, and add to this logarithm the value of log b; from this sum subtract log a and the remainder equals log y.

From the statement of our example we have, by using the tables,

log b = log 6 ft. $2^{7}/_{8}$ ins. = 0.79516
log a = log 8 ft. $7^{11}/_{16}$ ins. = 0.93655; also

	a^2 =	74.6604
	x^2 =	30.4796
	$a^2 - x^2$ =	44.1808
Then, from the tables	$\log \sqrt{a^2 - x^2}$ =	0.82272
Adding	log b =	0.79516
gives	$\log b + \log \sqrt{a^2 - x^2}$ =	1.61788
subtracting	log a =	0.93655
gives	log y =	0.68133

Hence from the tables y = 4 ft. $9^{5}/_{8}$ ins.

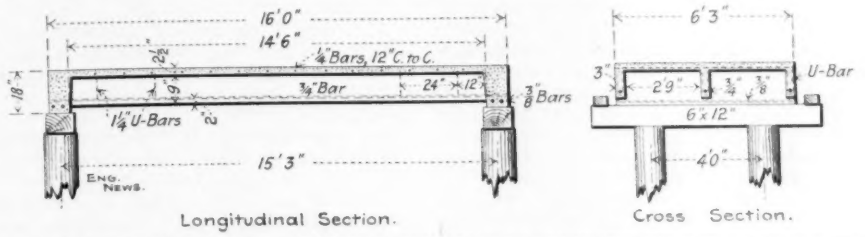


FIG. 1. LONGITUDINAL AND TRANSVERSE SECTIONS OF RANSOME CONCRETE-STEEL FLOOR OF 14½-FT. SPAN.

In conclusion, permit me to say, that I think the engineering and architectural professions are greatly indebted to Engineering News for its publication of "Smoley's Tables," as their advent has reduced the drudgery of the calculations of framed structures by fully one-half, and the writer hopes that his modest suggestions may tend to reduce tedious work along other lines.

Yours respectfully Francis D. Davis.
83 Auburndale Ave., East Cleveland, O., Dec. 10, 1902.

A Method for Strengthening the Hudson River Tunnels.

Sir: Twenty years ago I wrote my graduating thesis on the Hudson River Tunnel, which is once more in process of construction after years of practical abandonment.

To an engineer familiar with the physical characteristics of the Hudson River silt through which this and the proposed new tunnels will pass, the prophesy that the present method of construction will not prove equal to the task of supporting the traffic of heavy trains appears to be well grounded. This fact led me some time ago to design the plan for reinforcing tunnels built in soft material, shown in the accompanying drawings.

The invention consists essentially in providing a solid continuous concrete girder under the roadbed and exterior to the tunnel, having sufficient mass to take up the vibrations due to heavy express trains as well as the strength to distribute the weight evenly over a large area of ground. By this means a very solid foundation is provided for the roadbed, and at the same time the tunnel shell is relieved of all strains except those for which its design alone fits it, i. e., external compression strains. A further advantage is that the total weight of the completed structure more nearly approximates the mass of the material excavated from the tunnel so that there will be less tendency for any buoyant action to interfere with its stability.

The concrete girder shown in Figs. 1 and 2 could be constructed under the tunnel shell by removing one or two of the cast-iron segments in the floor of the lining and driving a narrow drift from this small opening, longitudinally for a length of 50 ft. On the floor of this drift would then be laid 8 ins. of concrete and on this foundation would be bedded, as shown, a number of steel rods (a) about 2 ins. diameter; the drift would then be entirely filled with concrete and the cast-iron segments replaced. By dividing the foundation into three narrow trenches, as shown, and building them consecutively, only a small area of the tunnel floor will be unsupported during construction, and this for only a short distance. These small openings in the floor of the tunnel could be made 50 ft. apart at several points and drifting carried on from them simultaneously. The steel tension rods could be rolled with cross-surface corrugations so that they would obtain a perfect anchorage in the concrete. This construction would form a continuous girder of great strength in which the cement-enclosed steel rods would act as the lower chord and the cement-enclosed cast-iron tunnel shell would act as the upper chord, a combination admirably suited to the needs of a subterranean girder having a continuous bearing. The steel rods would be provided with screw couplings distributed so as to break joints in the concrete mass.

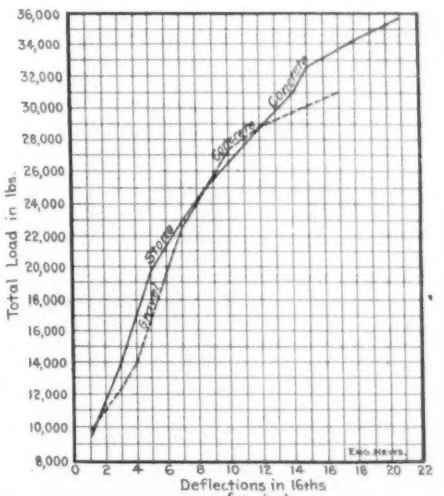


Fig. 3. Diagram Showing Relative Deflections of Broken Stone and Gravel Concrete Floors of 14½-ft. Span.

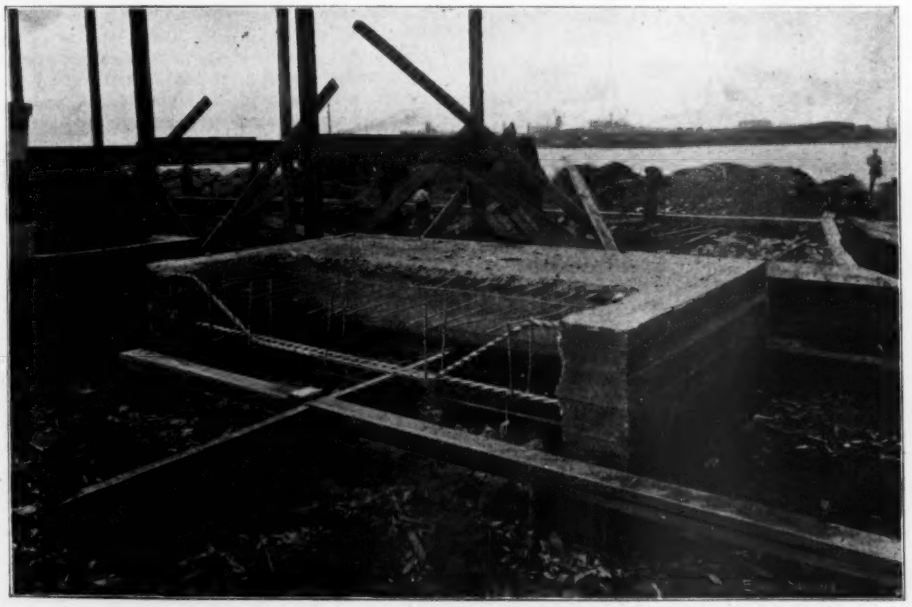


FIG. 2. VIEW OF RANSOME CONCRETE-STEEL FLOOR, WITH CONCRETE BROKEN AWAY TO EXPOSE METAL REINFORCEMENT.

Fig. 2 shows a modification of my proposed tunnel, in which the cast-iron segments composing the floor of the tunnel are left out. The segments of the tunnel shell on each side abut directly upon the concrete foundation and are fastened to it by suitable anchor bolts (Fig. 3). This plan would reduce the cost of the tunnel by the number of segments which it saves in the construction, which, in the case shown, is one-sixth. In constructing the tunnel the floor segments could be used over and over again by carrying them forward to the header shield after they had been replaced by the concrete floor girder some distance back from the tunnel heading. In order to facilitate the removal of the iron segments, a short key segment with straight sides is provided in the center of the invert, as shown in Fig. 1.

A tunnel in soft material in some degree bears a resemblance to a floating ship: as long as the ship has the continuous support of the water under the keel all is well. In the tunnel I propose it is the continuous and even support of the moving loads in the tunnel by the keel-like girder which I think will assure the efficiency of my plan.

Jesse W. Reno, E. M.
351 West 35th St., New York, Dec. 15, 1902.

Notes and Queries.

The editor of the "Lynn Item" is our authority for stating, in answer to a query, that the author of "Meest McDonough's Bias," printed in our issue of Nov. 27, is Mr. Henry Manley, Jr., of West Roxbury, Mass., son of Mr. Henry Manley, M. Am. Soc. C. E., and for many years connected with the engineering department of the city of Boston. The son is also a civil engineer, now employed in the construction of the Swampscott sewers.

The editorial on "Heat Resistance" on page 475 of our issue of Dec. 4 contains an error in the three algebraic equations which leads to an indeterminate solution. The paragraph in which the error occurs (top of 3d column) should be changed to read as follows:

Suppose we find that the total resistance of a certain non-conductor may be represented by the figure 10, and that similar pieces all give the same figure. A piece of

half the thickness of the others gives the figure 8, and two pieces, of the full thickness, in contact, give 16. What is the resistance of the surface exposed to the air in either piece, of the surface in contact with another surface, and of the interior of the body itself? Let the resistance of the material of the full thickness be represented by A, and of half the thickness by ½A, that of the surface exposed to air by a, and that of the surface in contact with another surface by c. We then have for the three cases:

Resistance of one piece A + 2a = 10
Resistance of two pieces 2A + 2c + 2a = 16
Resistance of one thin piece ½A + 2a = 8

These three equations contain three unknown quantities. Solving the equations we find A = 4, a = 3, and c = 1.

COMPARATIVE LOADING TESTS OF STONE AND GRAVEL CONCRETE-STEEL FLOORS; RANSOME SYSTEM.

An interesting loading test of Ransome concrete-steel floors was made under the direction of the Bureau of Buildings of New York city on Sept. 23 and 24, 1902. Three floors were tested, but interest is confined principally to two of them which were of 14½-ft. span and identical in all particulars except that gravel was used as the aggregate in one and broken stone in the other. The drawings, Fig. 1, shows the construction of these two floors of 14½-ft. span. The construction of the third floor is shown by Fig. 2, which is a view of the floor with a portion of the concrete broken away so as to expose the metal reinforcement. Two of these smaller span floors were built, one of gravel concrete and the other of broken stone concrete, but the gravel concrete floor only was tested.

The four floors were built on Aug. 20, two with concrete composed of one part Lehigh Portland cement, two parts of King & Co.'s sand and four parts of King & Co.'s roofing and paving gravel, mixed, and two with the same proportions of cement and sand, but with an aggregate of four parts of ¾-in. screened trap rock instead of gravel. The steel used was in the form of cold twisted square rods, having an elastic limit of about 62,000 lbs. per sq. in. for ¼-in. bars, and 56,000 lbs. for ¾-in. and ⅞-in. bars, and an ultimate strength of about 85,000 lbs. per sq. in.

In loading the floors for testing two 2 × 12-in. planks were laid side by side longitudinally over the middle beam of the floor and pig iron was loaded centrally over these planks, thus confining the load to the center beam.

The gravel concrete floor of 9 ft. 2 ins. span was first loaded and the load was applied until the pig iron supply was exhausted without sign of failure or injury. At the time loading was stopped the weight on the arch was 110,218 lbs., or 4,007 lbs. per sq. ft. of panel area. This load produced a deflection of 1-16 in.

Of the two 14½-ft. spans that made of gravel concrete was first loaded and the record of loads and corresponding deflections is given by the diagram, Fig. 3. The first cracks observed occurred between loads 28,652 lbs and 30,952 lbs., and consisted of five vertical cracks at regular intervals near the center of the span and extending upwards 5 or 6 ins. At 30,952 lbs. diagonal shearing cracks appeared about 2 ft. from each support, and at 35,800 lbs. these cracks had opened about ¼-in. and loading was stopped. The stone concrete span of 14½ ft. was next loaded, and as will be seen from Fig. 3 the deflections followed very closely those of the gravel concrete span for corresponding loads. In this span the five vertical cracks began to appear at 25,477 lbs. load and at regular intervals from the center of the span; the shearing cracks developed about 2 ft. from each support at a load of 28,765 lbs., and at 32,784 lbs. they had opened up to from ⅛-in. to ¼-in. This span remained loaded until Aug. 29 without further signs of failure. In addition to the cracks mentioned above, others opened up in the top of the slabs at their junctions with the supporting walls.

AN INTERNATIONAL BOUNDARY COMMISSION has about completed work upon the boundary between Nicaragua and Honduras. The Commision consisted of one engineer and one lawyer representing each republic. It began work in February, 1900, and the boundary has now been agreed upon from the Gulf of Fonseca to the Portillo de Totecasinte (near Jelapa), about half the distance from ocean to ocean. The remainder of the boundary is under discussion by the Commission. Mr. Emil Mueller, C. E., is the engineer member for Nicaragua

WATER TANK WITH HEMISPHERICAL BOTTOM AT WASHINGTON HEIGHTS, CHICAGO.

The Washington Heights district of Chicago, near the southwest limits of the city, had originally an independent water supply system which was established before the town was absorbed by the city of Chicago, and which has since been improved by the city. The supply was formerly drawn from artesian wells, but these are now only held in reserve. The present supply is from Lake Michigan, by means of an 8-in. main from the Hyde Park (68th St.) pumping station, while a 16-in. main is being laid from the Central Park Ave. pumping station. These mains deliver the water to three storage reservoirs 25 ft. diameter and 16.6 ft. deep, the storage capacity being 140,000 gallons. The elevation of the district being 80 ft. above Lake Michigan, a re-pumping station is in service, making a separate water supply system for a district containing about 10,000 people. This station is at an elevation of about 40 ft., and the water is pumped from the reservoirs to an elevated tank, which furnishes pressure when the pumps are not working, and therefore gives continuous fire protection. The elevated tank was formerly of wood, but in 1901 a new steel tank of interesting design was built, having a capacity of 180,000 gallons.

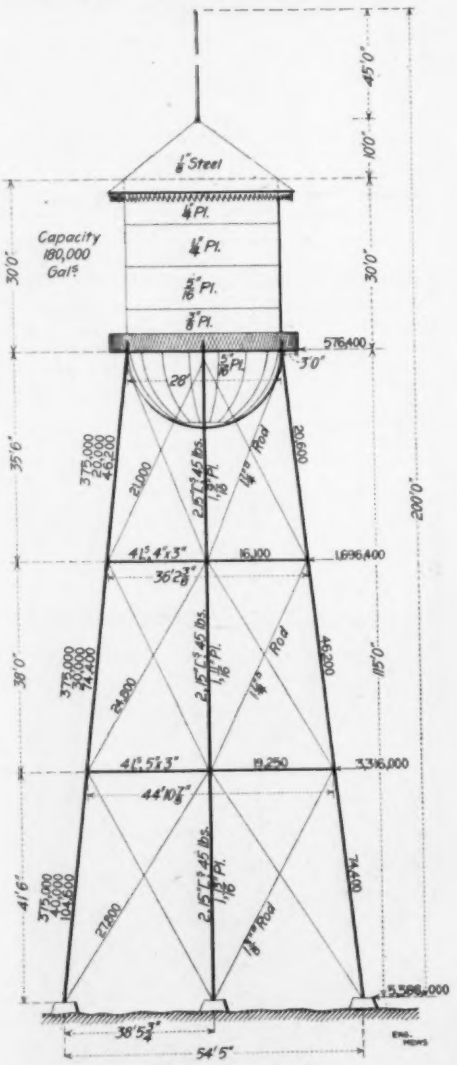


Fig. 1. Water Tower with Hemispherical Bottom at Washington Heights, Chicago.
Chicago Bridge & Iron Co., Builders.

This new tank consists of a cylindrical section 28 ft. diameter and 30 ft. high, with a hemispherical bottom of 13 ft. 11 11-16 ins. inside radius. The cylindrical portion has four courses of plate about 6 ft. 10 ins. high, each set inside the one below and put together with single riveted circular seams and double riveted vertical seams, except that in the bottom course the vertical seams are triple riveted. The bottom course has four ⅜-in. plates; second course, four 5-16-in. plates; third course, five ¼-in. plates, and top course, six ¼-in. plates. The hemispherical bottom is riveted directly to the cylindrical shell, so that there is no break or angle at which distortion may occur. This portion of the tank is built up of plates 5-16-in. thick, with double riveted seams, and a dished bottom plate to which the segmental plates are connected by a single riveted lap joint. The rivets are ⅝-in. diameter in the two top courses, ⅝ and ¾-in. in the two lower courses, and ¾-in. in the bottom. Through the bottom passes a 12-in. cast-iron pipe, with expansion joint. The tank is covered by a conical roof of ⅛-in. steel, riveted to 12 bent plates on the inside of the upper edge.

The tower is composed of four legs or columns on concrete pedestals 38 ft. 5¾ ins. c. to c., and is divided into three panels by two horizontal lines of struts. Each column consists of two 15-in. 45-lb. steel channels, set back to back, with a cover plate 11-16 × 17 ins. on the inside, and single lacing on the outside. The columns are in three sections, spliced together just above the level of the horizontal struts, which are riveted girders, having single angles for the flanges and web members. The lower strut is 3 ft. deep, and the upper strut 2 ft. 6 ins. deep. In each panel there is a vertical bracing consisting of two diagonal rods with loop ends fitted to pins in the column shoes, in the end connection plates of the struts, and in pin plates on the tops of the columns. Around the top of the tower proper, level with the base of the cylindrical portion of the tank, is a circular balcony girder, with 5-16-in. horizontal web, 36 ins. wide, supported by gusset plates. This takes up any horizontal strain, and serves also as a footwalk, being fitted with a latticed hand railing along its outer edges. The whole design is arranged with a view to securing stiffness and rigidity as well as ample strength in the tower.

The most interesting feature of the whole design lies in the connection of the tower columns to the tank, which in many similar structures is a somewhat weak feature, of more or less awkward construction. This matter was referred to in our issues of Nov. 21 and Dec. 5, 1901, in connection with the failure of the water tower at Fairhaven, Mass. In the Washington Heights tower, the columns are carried up by heavy angles extending above the channels; these fit against the lower cylindrical course of the tank, and are riveted directly to it, a 5-16-in. plate 48 ins. wide being placed between each column and the shell of the tank. In this way the load is transmitted directly to the tower, and no supporting girders, shelf angles, brackets, or other connections are required, while the weight of water in the bottom causes no working or tendency to distortion at the supports, as is the case when such connections as above mentioned are used, involving sharp changes of direction in the lines of strain. The arrangement used in this tower is not only of good design, but is simpler in construction than many other arrangements used for tanks having water bottoms below the cylindrical shell.

The Washington Heights tower was designed and built under the supervision of Mr. John Ericson, City Engineer of Chicago, the work being carried out by the Chicago Bridge & Iron Co., which company has also built a number of other water towers of generally similar design. For plans and other information we are indebted to the builders.

SPLICED JOINTS IN THE COLUMNS OF STEEL-FRAME BUILDINGS.*

By John Stephen Sewell,† Captain, Corps of Engineers, U. S. A.

In excellence of design, steel details in fireproof buildings have until recently been distinctly inferior to those used in bridges, especially railroad bridges. It is probable that there is not the same necessity for rigid compliance with the requirements of theory in building construction, because here several different classes of materials are generally used in juxtaposition, and they reinforce

*See also an article entitled "Columns for Buildings," by Capt. J. S. Sewell, in Engineering News of Oct. 23, 1902.

†Engineer-in-Charge, New Building for Government Printing Office, Washington, D. C.

each other to some extent; the probability that a single poor detail may be the cause of a disastrous failure is also much more remote in a building than in a bridge, where each detail is like a link in a chain, which is not duplicated. In other words, the failure of one detail in a building will rarely produce a general collapse, while the case is very different for the bridge. However, the current designs of steel-frame details for buildings show great improvement over those of a few years ago; indeed, in many cases, current designs leave very little to be desired.

But good design must go hand in hand with good workmanship, or it fails of its purpose. Good workmanship may save a poor design, but no excellence in design can make up for poor workmanship. There is no more vital point in a steel frame for a building than the column joints or bearings; and, singularly enough, there is none where more careless execution is to be found. The writer has examined, first and last, many hundreds of column bearings in his own and other work. The result of his observations is that about one-third of all the column bearings in the average steel-frame building show gaps varying from a sixteenth of an inch to as much as half an inch, in extreme cases. This is generally due to the fact that both upper and lower columns are faced off obliquely at the abutting ends, so that they touch at only one point or over only a small area; of course the errors are usually additive and not mutually compensating.

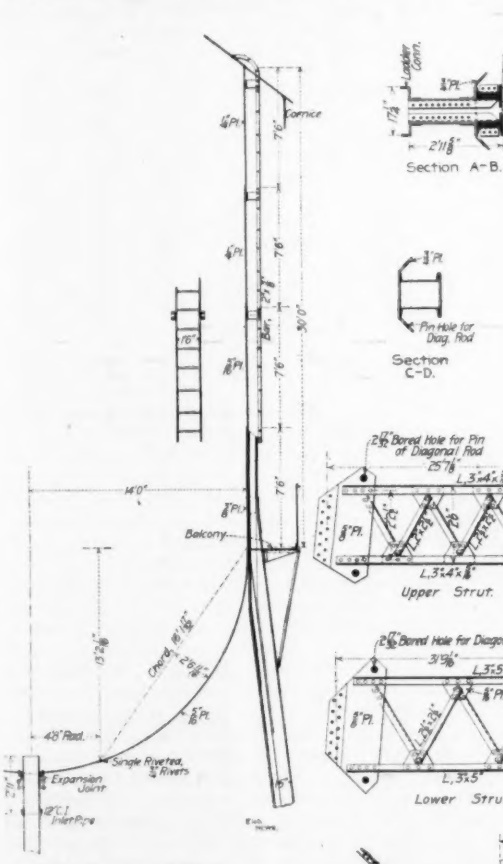


Fig. 2. Details of Tank.

To show how little variation from uniform bearing can be safely allowed, assume a column made of two 15-in. 55-lb. channels, placed back to back, and latticed. Suppose the story height is 12 ft., and that the load on the column averages 16,000 lbs. per sq. in.; this would give a total load of 517,760 lbs. Suppose further that the column is faced off obliquely at its lower end, so that two corresponding flanges of the channels bear on the column below, while the other flanges and the web do not bear. The eccentricity would, in this case, be about 6½ ins., producing a bending moment of 3,365,400 in.-lbs. If one story length of the column be considered as a beam supported at the two ends, with a span of 12 ft., and subjected to a constant moment of this amount, the maximum fiber stress due to eccentricity alone will be 26,860 lbs. per sq. in., and the inclination of the curve of mean fiber at either end will be tan-1 0.009. From this we find that 15 times 0.009, or 0.135 in., is the amount of gap that must exist under the non-bearing flanges to allow the full deflection to take place. That gaps as great as this and much greater often occur can be readily verified by a close inspection of column bearings in almost any large steel-frame building in process of construction.

Of course, in actual practice, no such strains and deflections as above deduced ever occur; if they did, the fact would be plainly apparent. Columns generally extend through two or more stories; they are stiffened at the joints by splice plates, and at floor levels by the connection of beams and girders; they are often greatly stiffened by the surrounding masonry at intermediate points. But all of these sources of stiffness would not remove more than half of the moment due to eccentricity, if it could exist in the column as such. As a matter of fact, it probably does not exist as such, for a reason which can be illustrated by further reference to the column assumed above. This column would probably be spliced with two ¾-in. × 18-in. plates, long enough to take in about four ⅞-in. rivets in each row, on each side of the splice. Thus there would be sixteen ⅞-in. rivets available for transmitting loads through the splice, though not put there for that purpose. At 11,000 lbs. per sq. in., their total value in single shear is 105,760 lbs. The figured load of the column would be 517,760 lbs., but the actual load at any time would probably be considerably less, and while the *rivets in the splice plate would be dangerously near failure*, they would probably still stand up under it and transmit it, with what assistance they might receive from the small area of column ends in actual bearing. The writer is convinced that this is the only possible explanation of why some steel frames have not failed before this. He has figured several cases that he happened to notice, and it seems to come about, as a sort of incident to the usual designs of column splices, that the rivets in the splice will usually transmit the column load, although with stresses that reduce the factor of safety almost to unity. As a chain is no stronger than its weakest link, a steel-frame building with many poor column bearings certainly has not the load-carrying capacity its designer expected it to have, and the factor of safety has been drawn upon to the extent of almost 100% to make the building stand at all. Of course, a very little corrosion at the splices will cause complete or partial failure of the building; a serious increase in vibrations or in customary loads may in a short time bring about the same results.

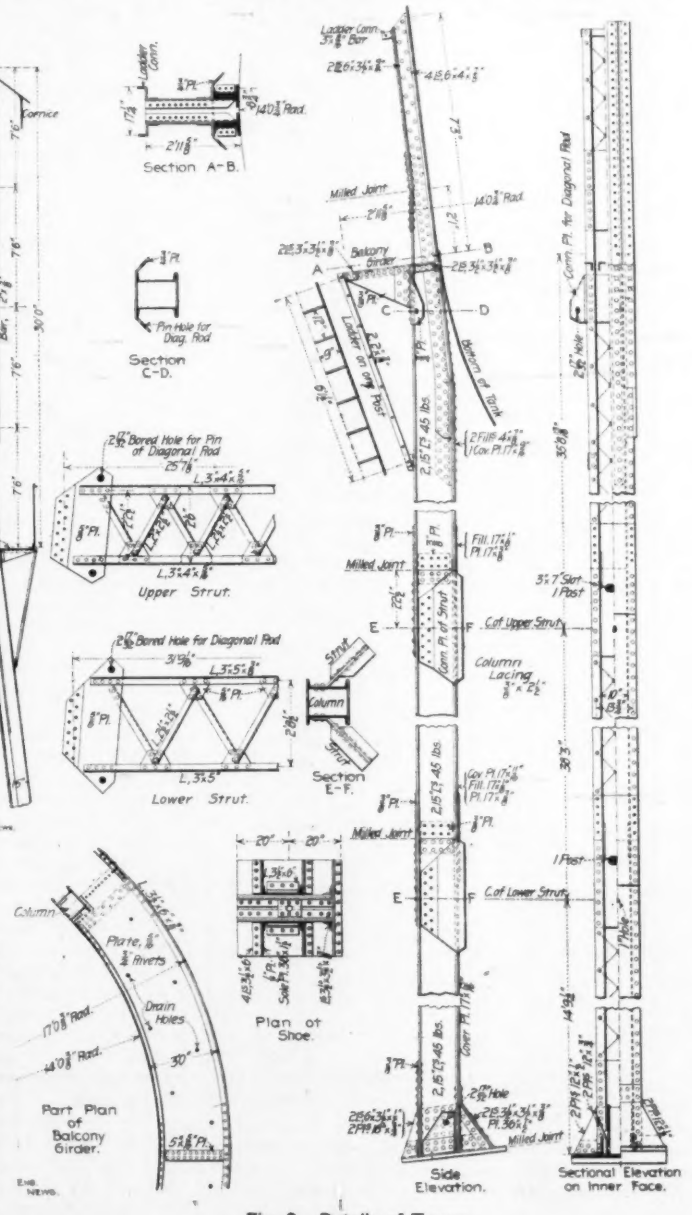


Fig. 3. Details of Tower.

It may be argued that the modern steel-frame building shows a decided tendency to stand up, notwithstanding the poor column bearings; in fact, this argument was used to the writer by a representative of a very large and prominent building concern in reference to a modern building put up by them, in which poor column bearings and other defects were glaringly apparent. It is quite true—the buildings undoubtedly stand. But if it is good engineering and good business to get along with such a narrow margin of safety at one point, it is better engineering and better business to reduce it in an equivalent amount all along. This would lead us to designing girders, columns and beams with stresses under their working loads about equal to the elastic limit of the material, and would result in large savings; of course the number and size of rivets in the column splices would have to remain the same as as present.

However, no well informed and thoroughly honest engineer would recommend the deliberate assumption of any such risk as would be involved in the scanty designs above suggested. It then remains to inquire whether the column bearings can be improved at reasonable cost so as to give fair contact (a condition always assumed in design) throughout the entire cross-section. The writer is convinced that it can be done; that it will cost almost nothing in money, and only a little more in the way of attention on the part of all concerned in the fabrication of the columns. Taking again the channel column already discussed, if it is three stories high, or 36 ft. long, and has its greatest width of cross-section equal to 18 ins., its ratio of length to thickness is 24. It certainly seems not beyond the bounds of reason to demand that some rectilinear element of this column, as nearly as possible parallel to its actual axis, be assumed and marked, and then set perpendicular to the plane of the rotary head in the facing tool within 1-20 of an inch. This degree of accuracy ought to be within the capacity of any workman intelligent enough to be trusted with a rotary facer at all. If it is realized, and the tools are set so as to cut uniformly and not too fast, the ends of the column will be true to within 1-480 of an inch. The same element used to adjust the column in the facer should be again used for plumbing in the field, and, for this purpose, should be permanently marked. If all column ends are true to within 1-480 of an inch, no joint in the field can be open more than 1-240 of an inch. Considering again one story of the 15-in. channel column as a beam supported at the ends, and subject to a constant bending moment due to eccentricity of bearing, a gap of 1-240 of an inch will be closed by deflection when the fiber stress due to bending is only about 800 lbs. per sq. in.,

which, of course, is a perfectly reasonable draft on the factor of safety, even if it exists in its full amount. Even if the rivets in the splice yielded enough to allow this to take place, their strength would not be seriously impaired. The actual stress would, of course, be less than that figured above, and would probably not exceed, in any case, 400 lbs. per sq. in.

Many persons may be skeptical as to the actual existence of so much careless work as is herein alleged; it is a fact, nevertheless. A column bearing may be open almost ⅛-in. without the fact being apparent, except on a very close examination. The outer skin of metal at the bearings is often drawn down with a hammer by the workman, so as to make it appear tight when it is not; a little paint is equally effective. It is rather a ticklish business for one who is not accustomed to work aloft to inspect column bearings at the only time when such inspection is of any use. Owners are rarely willing to pay for the right kind of inspection, either in the shop or the field. Professional inspectors in the shop rarely take any great pains to discover whether a column is faced off true or not; they do not see the work go together, and probably the necessity for such precautions never occurs to them. A general contractor who has undertaken to put up a modern building in record-breaking time is very apt to protest vehemently against any corrections that cause delay, so long as the work will go together at all. For all of these reasons, the workmanship on modern steel frames is far below the standard of efficiency corresponding to the designs and unit stresses usually employed. It would be good business to skin the materials a little and put the savings into better workmanship; there is a margin both for increasing the safety of the finished work and for an absolute money saving besides.

In the writer's recent work, where a column has not been fully spliced, and the joint was slightly open, he has compelled the erectors to plumb both the upper and lower columns, and then take a cut between them with a hack saw; then let down the upper column, keeping it plumb, take another cut, and so on, until there was fair contact throughout. To do all this to a 15-in. channel column with ¾-in. cover plates, takes about two days for two men. Where the gap was too great to be corrected in this way, the column was returned to the shop for refacing and inserting a tight filler to make up for the lost metal.

These and some other requirements as to workmanship on rivets at splices, etc., combined with a thorough but reasonable inspection by a trained engineer, made the actual flat cost to the contractors of a recent piece of work containing 6,500 tons of steel, about $2 per ton more than that of average current work of a similar nature.

The contractors in this case showed every desire to do good work; the great number of poor bearings took them greatly by surprise. This would indicate that in current work the bearings must receive scant attention, for the cases of faulty contact are sufficiently numerous to be a subject of general knowledge if they were closely inspected.

If the contractors had realized from the start the frequency of the faults they had to correct, they might easily have taken steps to eliminate them, which would have kept the extra cost well within $1 per ton—probably below 50 cts. per ton.

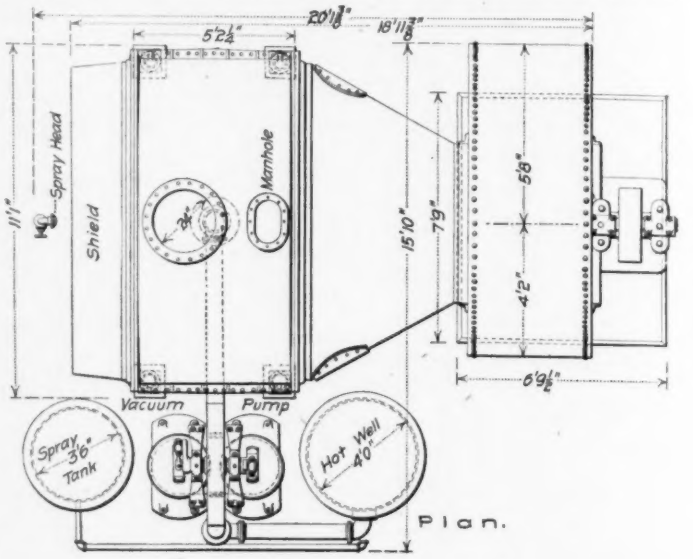
The grade of workmanship exacted was plainly called for by the specifications. In order to pay for it, if necessary, the steel was designed for unit stresses of 18,000 lbs. per sq. in. instead of 16,000. By this means, 800 tons of steel at $75 per ton were saved. Had the entire extra cost of $2 per ton been paid by the owner (the United States) there would still have been a net saving of $47,000—and the building has a greater factor of safety than if designed at 16,000 lbs. and put up in the ordinary way.

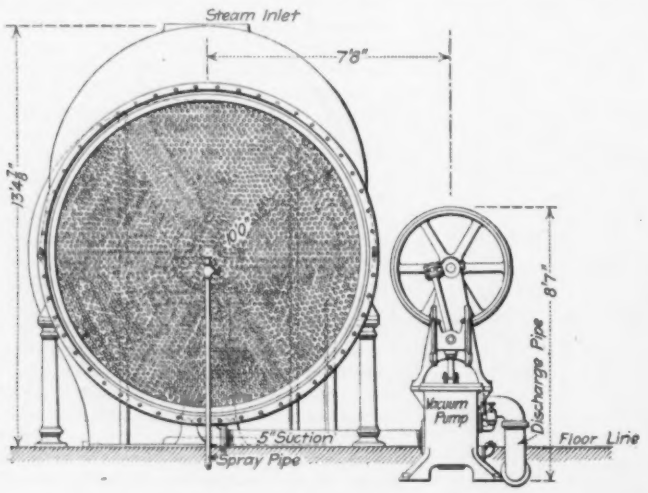
This question of column bearings is one of the many instances to be met with in building construction, where the execution is not equal to the design. In very few engineering works is so low a standard of workmanship current as in building construction. Building contractors constantly accept risks in the way of careless work that would ruin an engineering contractor and the engineer in charge of the work. The fact that so few buildings fail only proves that there is a large margin in the material used in their erection. The amount of material is above the limit of true economy, so long as the standard of execution is so far below it. Some material could well be sacrificed to a higher standard of work, until the latter becomes common and is demanded. Then a return to present unit stresses should be made. Meanwhile, except in special cases, owners must be educated as to the value of efficient inspection, and building departments convinced that such inspection will be furnished, before the first step can be made. So far as columns are concerned, the advent of the reinforced concrete column may render such education unnecessary before it has been accomplished.

A "TOWERLESS COOLING TOWER" AND SURFACE CONDENSER COMBINED.

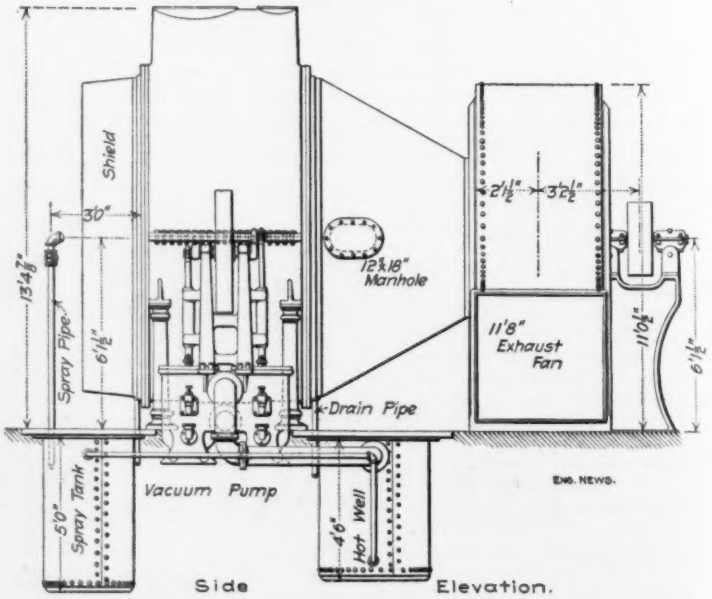
We illustrate herewith a novel and very interesting system of condensing for steam engines, particularly applicable where the supply of condensing water is limited and where space available or other considerations forbids the use of a cooling tower. As most of our readers know, there has been a great increase in the use of condensing steam engines during the past twenty years. American stationary engine practice early developed in the direction of high-pressure engines exhausting directly to the atmosphere, and the use of condensers was considered a complicated fad. It is only in recent years that the economy resulting from the use of condensing engines has come to be generally appreciated by steam users, so that the condenser has assumed its proper place in stationary practice.

It is now very frequently desired to use a condensing engine where the supply of condensing water is limited, and resort must be had to some method of cooling the water so as to use it over and over again. Cooling ponds were the first plan for effecting this, and more recently cooling towers of various types have come into extensive use.





End Elevation.



Side Elevation.

A COMBINED SURFACE CONDENSER AND COOLER FOR CONDENSING WATER.
Cosmopolitan Power Co., Chicago, Builders.

The apparatus herewith illustrated, however, requires no cooling tower. It is simply a surface condenser in which, instead of using water to condense the steam, the cooling of the tubes is effected by the combined action of a current of air and a water spray. We illustrated a surface condenser in which air alone is used in our issue of Oct. 2. Such a condenser requires, of course, a very large extent of cooling surface per unit of power. In the present apparatus, by the use of a

fine spray of water with the air current a much more effective cooling of the tube surface takes place, and a very much smaller condenser is possible for a given power, although it is still considerably larger than an ordinary surface condenser in which the tube surface is in contact with solid water.

The particular condenser illustrated herewith has a cylinder 10 ft. in diameter and 5 ft. long closely packed with 1-in. copper tubes. The exhaust steam is on the outside of the tubes, while the air current and cooling water spray pass through the tubes. The tubes are expanded in one tube plate and fitted with glands and stuffing boxes at the other as usual in surface condenser construction. At one end of the condenser is the cold water or spray pipe, fitted with a rose or spray head having openings about 0.025 in. diameter. For the largest condensers the pipe used is only 1½ ins. diameter. An average pressure of 25 lbs. is sufficient to distribute the water over the tube plate, the rose being set about 30 to 48 ins. from the plate, and being of such size and shape that the conical shower of spray is delivered over the entire area of the tube plate. A circular shield prevents splashing, and water which drips from the tube plate falls into a spray tank, from which it is again drawn by the injection pipe. At the opposite end of the condensing chamber is an exhaust fan which draws a current of air through the tubes, this air carrying with it the injection water as a finely divided spray, which is evaporated by the heat which it absorbs from the tubes. A conical spray collecting chamber is interposed between the tube sheet and the fan casing, where any water coming through is collected and drained back to the spray tank. The air discharged from the fan has a temperature of 110° to 170° F. The rate of condensation is of course influenced by the speed of the fan, increasing with the speed up to certain limits.

The condensed water is delivered to the hot well by an Edwards vacuum pump (Eng. News, June 12, 1902). In this pump, foot and bucket valves are dispensed with, and if there is no head on the discharge the only valves used can be examined without stopping the pump. The condensed water flows by gravity from the condenser into the base of the pump, and is forced through ports into the working barrel by a plunger having a conical base, the operation being performed without noise or shock.

The condenser is being manufactured and sold by the Cosmopolitan Power Co., 184 La Salle St., Chicago, Ill. It is made in sizes from 48 ins. to 10 ft. in diameter, and of three classes: A, for vacuum service; B, for such commercial purposes as the distillation of water, and C, for simple engines or pumps where a vacuum is not desired. They are all of the same general construction, but the first has a cast-iron shell (to sustain the atmospheric pressure), while the others have shells of steel plate and contain more cooling surface per horse-power, as the steam condenses less readily where no vacuum is maintained. They also have lighter tubes than the vacuum condenser.

Among condensers of this type recently built may be noted the following: A 54-in. condenser for John T. Stanley's soap and fertilizer works in New York City; 60-in. condensers for the Saxony worsted mills at Newton, Mass., and the Arbuckle sugar refinery at Brooklyn, N. Y.; 72-in. condensers for the Kelley & Lysle Milling Co., of Leavenworth, Kan., and the Waynesboro (Pa.) Electric Light & Power Co.; and a 96-in. condenser for the Mexican Central Ry. at Aguascalientes.

A 36-in. condenser was tested at the builders' shops in Chicago on Nov. 11 by R. W. Hunt & Co., of Chicago, and a copy of the report on this test is given below:

The condenser is 36 ins. diameter and contains 296 1-in. tubes, 5 ft. long between tube sheets, giving a cooling surface of 387.5 sq. ft. The condenser was connected to a Murray Iron Works Corliss engine (12 ins. × 30 ins.) by a 5-in. exhaust line, which was increased to 8 ins. at the condenser. The exhaust fan connected to the condenser was a 55-in. Sturtevant fan driven from a countershaft, which, in turn, was belted to a motor.

The vacuum pump used during the test was a Burnham pump (8 × 14 × 16 ins.). This pump did not give a very high vacuum, and its connection to the condenser was faulty, as the pump suction pipe was higher than the drain pipe of the condenser. The condensing water or spray water was pumped from a tank set in the floor by a Smith-Vaile pump (3 × 2 × 4 ins.). All the spray water caught in the ends of the condenser and in the fan was returned to the spray water tank and used over. A constant level was maintained in the spray tank by a supply of city water.

The condensed steam was measured by running the discharge from the vacuum pump to a carefully measured tank. The condensing water evaporated was equal to the amount of city water necessary to maintain a constant level in the spray tank, and this water was carefully measured in a calibrated tank. The temperatures of the condensed steam, the city water, the waste spray water returned to the spray tank, and the spray water before being pumped to the condenser, were all carefully noted; also the temperature of the exhaust from the fan, and the power necessary to drive the fan motor. Indicator cards were taken both with and without the condenser.

With the arrangement which you have for testing, it was impossible to make a run of more than one hour, as the condensed steam tank filled up in that length of time. The performance of the vacuum pump was also unsatisfactory as the discharge was not steady and constant, due to the fact that the suction pipe was higher than the drain pipe in the condenser.

Duration	1	hour.
Condensed steam	1,545.3	lbs.
Condensing water lost	1,193.8	"
Spray water pumped (calculated)	6,282.0	"
Temperature condensed steam	153°	F.
" city water	59°	F.
" spray water	112.33°	F.
" waste condensing water	125°	F.
" air	80°	F.
" fan exhaust	126°	F.
Speed of fan, revs. per min.	810	
Air exhausted by fan (calculated)	21,243	lbs.
Indicated horse-power	51.44	HP.
Steam per Ind. H. P.	30.04	lbs.
Heat in exhaust steam, above 32° F.	1,754,379	B. T. U.
" in condensed steam, above 32° F.	187,492	"
" abstracted from steam	1,566,887	"
" in city water, above 32° F.	32,244	"
" in exhausted condensing water, above 32° F.	1,368,969	"
" absorbed by condensing water	1,336,725	"
" absorbed by air	165,058	"
Radiation loss	65,104	"
Condensed steam per sq. ft. of cooling surface per hr.	3.98	lbs.
Condensing water lost per lb. of condensed steam	.77	lb.

THE REORGANIZATION NEEDED IN NEW YORK BEFORE CANAL CONSTRUCTION.

By Albert J. Himes,* M. Am. Soc. C. E.

In view of the probable radical enlargement of the New York canals, which is again the subject of current discussion, it seems pertinent to consider the administrative methods by which such an improvement can be best and most economically executed. A change in the present canal organization, however, would require an amendment to the constitution, and it is therefore necessary that a decision in the matter be reached, earlier if possible, but certainly not later, than a decision to carry out the improvement.

At present all matters pertaining to the New York state canals are within the jurisdiction, either separate or combined, of the State Engineering Department and the Department of Public Works. This dual arrangement, by which the responsibility is divided between the State Engineer, an elective officer, and the State Superintendent who is appointed by the Governor, has resulted in the building up of a large and expensive organization, which is in every way absolutely unfit and incompetent to properly carry out an undertaking which involves the expenditure of millions of dollars.

To many who are not intimately acquainted with the operation of these departments or with the execution of great engineering works, this sweeping statement will cause surprise and the reasons for it should therefore be carefully read. These reasons have been tested by experiences that would fill volumes and which manifestly cannot be readily published, but there are many prominent citizens who are qualified by their own experience to judge of their accuracy, and who would willingly lend their aid to a movement for correcting the existing evils.

For the purpose of clearly stating the subject it will be discussed briefly under three heads, as follows: (1) The office of State Engineer; (2) the dual management of the canals; and (3) the civil service system. But it must be noted that the reasons given are closely interwoven and mutually interdependent, and that much of the difficulty is due to the combination of evils rather than to any single one of those mentioned.

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OFFICE OF STATE ENGINEER.—The State Engineer is elected every two years. His salary is $5,000 per year and he is allowed $800 per year additional for necessary traveling expenses. The office is not a desirable one from a professional standpoint because the salary is too small and it is in no sense an introduction or assistance to something more attractive. A $2,500 income from some railroad position or from a private practice would be far more profitable because of the avoidance of many demands made upon the State Engineer for both time and money, and because of the possibilities of promotion or increase of business. What railroad company would think of getting for a $2,500 salary a chief engineer to carry out works costing more than $20,000,000? The idea is absurd.

The State Engineer must, in the discharge of his duties, travel throughout the length and the breadth of the state. Unlike a railroad man, he cannot travel free on his own line, and his hotel bills are not small. $800 per year is entirely inadequate to meet his necessary expenses and he must either remain in his office to the neglect of his outside duties or find some other fund from which to draw his expenses.

Two years is hardly sufficient time for a new man to become well acquainted with the canals and the duties of the office, and since a man must expect to step out at the end of that time, there is little inducement for him to make any great effort at thoroughness. If a new canal were under construction, he would be simply a figure-head receiving orders from his subordinates instead of directing the work himself, because it would be physically impossible to step into so large a work after it was well under way and exert a very marked effect upon its management in so short a time. Contracts would be already let and half completed, and though they might be drawn up and let in the loosest and most careless manner possible, yet the legal methods of correcting such evils are so slow that any attempt in that direction would only result in delaying the work until his term expired, when another man with different purposes might fill the office.

The State Engineer has so many duties as member of various commissions and boards that a conscientious observance of them all would leave little, if any, time for his regular engineering duties.

When the legislature is in session he must be obedient to its demands, and at times he is forced to lobby to the utmost to secure the funds necessary to run his department. This condition opens the door for interference with the appointment and control of his assistants, and is very demoralizing.

There is hardly one chance in a hundred that a state political convention will select an engineer because of his qualifications for the office. The office is at the tail end of the ticket and frequently goes begging. No good man will strive for it, and generally the party delegates know so little about engineering that with the best of intentions they are not in a position to prevent the nomination of an inferior candidate.

After a period of corruption in the state administration, the better citizens of both parties unite to elect a set of worthy officers, but little attention is paid to the office of State Engineer. If the candidates for Governor and the more prominent offices are acceptable, the ticket is elected. Then if the Engineer happens to be a politician of the lower class, the affairs of his department do not share in the general improvement that is supposed to follow. He is not directly dependent upon the Governor and will cater to his own political friends rather than adopt any radical measures of reform. In a word, the people's remedy for maladministration, electing a better man to the office, is not practically operative in the case of the State Engineer.

THE DUAL MANAGEMENT OF THE CANALS.—The office of Superintendent of Public Works is administrative in character and has to do primarily with the maintenance and opera-

tion of the canals. The office is filled by the Governor, which makes the department more responsive to a public demand than that of the Engineer.

Without discussing the fitness of the usual appointee to perform the nominal duties of the office, it may be stated unreservedly that he is never qualified by training or experience to exercise control over a great engineering work. The canal affords too many prizes to the party workers to permit its being placed voluntarily in the hands of a man whose sole aim would be its economical and efficient management. And yet in the event of the construction of a new canal the Superintendent would have complete control of all inspection over the whole work.

Most intelligent men know that an engineer who simply prepares plans and specifications for a piece of work, as does the State Engineer, but has no authority to enforce its proper performance, is utterly helpless after the letting of the contract. Yet such and worse is the position of the State Engineer of New York, for he not only has no right whatever to employ assistants to inspect the work, but is required by law to certify on the estimate for payment that it has been properly done!

A more glaring inconsistency would be hard to find, and although the framers of the law may have been and probably were actuated by honest motives, yet in effect it requires the Engineer to measure up and pay for completed work which may be performed in his absence and made to cover up and hide an unlimited amount of fraud. This is no idle speculation, for such things are not unknown among canal men, and the magnitude of the fraud is likely to be proportional to the size of the contract.

There are those who will say that the assistant engineers are constantly in the field and can readily detect and correct any improper work. It is true that these men stake out and measure up the work, but they are traveling about from place to place while in the field and are obliged to spend much time in the office. There is plenty of time during their necessary absence to pile up hundreds of yards of masonry without any mortar or to build a high embankment without any core wall to make it water tight. Practically an honest and energetic engineer may find means to circumvent many attempts at sharp practice, but that would be in spite of the law and not by its authority.

The State Engineer has certain powers not shared by the Superintendent and neither can accomplish much without the co-operation of the other. There usually exists a certain amount of official courtesy between the two and they struggle along with as little friction as possible. Yet if anything goes wrong, either department will demonstrate that the other is at fault, and if one department attempts to correct the other, its hands are tied and nothing can be accomplished.

The contractor himself is frequently at sea because the Engineer makes out his estimate and the Superintendent pays the money. Either department can embarrass him very much by negligence or delay, and if they give conflicting directions concerning the work, neither is disposed to yield until his wishes have been fulfilled. It is doubtless for this reason that the most successful canal contractor is usually in partnership with an active politician from each political party, who act as attorneys in pressing the claims of their client for liberality and concessions on the part of the state officials.

THE CIVIL SERVICE.—Like all other creations of man, the civil service system has its limitations and defects. When a young man of indolent habits, no technical education and limited experience, is able to pass the examination for assistant engineer—when a man appointed to the position of leveler, and being informed that he must furnish a level, appears on the work carrying a carpenter's spirit level—when assistant engineers seriously maintain that mud is solid rock, then it is in order for the civil service commission to explain the workings of its rules!

But granting that applicants for positions under the civil service are selected fairly and wisely and have entered upon their duties, it is soon discovered that their troubles have just begun. In assignment to work, in promotions, and in other ways, much favoritism may be shown and always at the instance of an influential friend. But these things are of small moment to an ambitious and honest man who is determined to succeed. His real struggle comes when in trying to perform his duty he arouses the antagonism of the contractor and finds to his dismay that he is a nonentity. Having no friend at court, not only is his judgment of no consequence, but he is not to be trusted and at the contractor's request is transferred to a station where there is less opportunity to come in contact with men who are reaping a profit from their dealings with the state.

And so each man soon learns that he is not to be judged and rewarded by his faithfulness and skill, but that to insure fair treatment and reasonable consideration he must seek the aid of a politician. He may have an idea of his own concerning the relative merits of instructions given by different persons in authority, but where those instructions are conflicting he will make no error so far as his own immediate future is concerned if he obeys the man with the strongest "pull."

During the expenditure of the $9,000,000 appropriation many young college graduates were employed in the Engineer Department, and the strongest influence on the canals that was exerted to secure proper construction was the good sense and honesty of these men. The statement of the Investigating Commission that the new construction showed an improvement in quality over that done in former canal enlargements was possible only because these men were anxious to do, and did, do their duty, so far as permitted by their experience and the instructions of their superiors.

Under the conditions above outlined, it is to be hoped that the reader will have no difficulty in accepting the statement made in the beginning, that the canal departments as at present organized are hopelessly incompetent to effectively carry out a large scheme of improvement. A remedy should be sought and put in operation as early as possible.

Should the present canal departments be confronted with a credit of $50,000,000 they would be completely staggered and the $9,000,000 fiasco would be like a speck in a clear sky compared with the disaster that would follow.

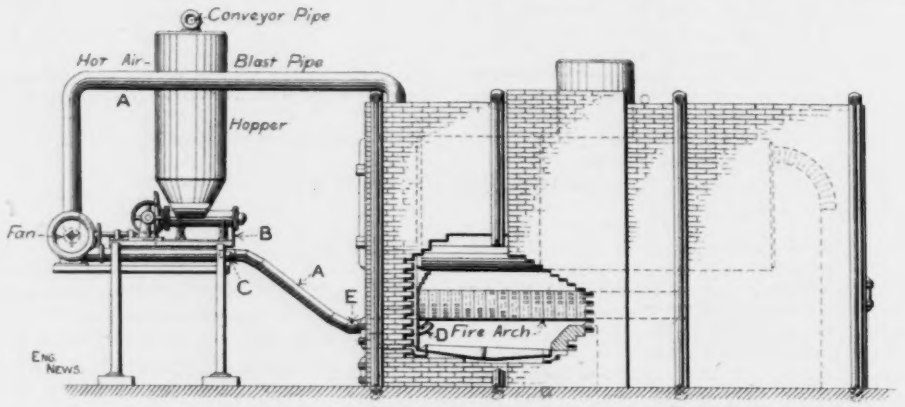
Concerning the possible remedy for such conditions, attention might be profitably given to the work of the Rapid Transit Commission of New York City. As yet no public criticism of its work has appeared and its organization seems to be very effective.

A NEW SYSTEM FOR BURNING POWDERED COAL

The multiplication of systems for burning powdered coal during the last year or two has been quite remarkable, and we have from time to time described such of these systems as seemed of most interest because of intrinsic merit or the fact that they were in actual use. In the accompanying cut we illustrate the general arrangement of another coal-dust burner, which is manufactured by the C. O. Bartlett & Snow Co., of Cleveland, O., and has been installed by that company at its own works, and also at the plants of the Indianapolis Water Co., Indianapolis, Ind., and of the McCormick Harvesting Co., of Chicago, Ill. The illustration shows the feeder and burner alone, but the full complement of apparatus for a complete plant includes, besides the burner, a machine for crushing the coal, a dryer, and grinding mills.

It is presumed that the crushing machine will be used only in case the coal to be used is in large sizes and crushing is necessary as a preliminary to drying. The dryer is of the compartment type, and will vary in size according to the amount of coal used. The grinding is done in buhr-stone mills and two of these mills, it is said, will grind about 20 tons per day sufficiently fine to pass an 80-mesh sieve. The dryer is said to reduce the ratio of moisture to 2%. In this dry powdered form the coal is delivered to the feeder and burner, which is described as follows by the builders:

The ground coal is stored in an iron hopper or tank above or near the boiler. An air pipe, A, is connected with feeder spout at the furnace and above the boiler in the breeching or stack, and a blower fan is attached to



THE ROWE AND BENDER POWDERED COAL FEEDER AND BURNER APPLIED TO A STEAM BOILER.
The C. O. Bartlett & Snow Co., Cleveland, O., Builders.

this pipe of sufficient size to furnish the necessary air for burning the coal dust. The operation is as follows:

The coal is conveyed by a special conveyor from the bottom of the storage bin to a spout, B. The speed of this conveyor controls the amount of coal used and can be changed by turning a hand wheel to feed faster or slower according to the amount of fuel desired. From the conveyor the coal is fed direct to the air spout, A. There is a nozzle, C, on the inside of the air spout, which concentrates the air as it strikes the coal as it comes down from the conveyor, which gives a thorough mixture of the coal with the air and at the same time prevents any danger of clogging. The coal is caught by the current of air and blown along the air spout to the furnace spout. Just before entering this spout there is another nozzle, E, which again concentrates and mixes the air with the dust just before it enters the feed spout, D. This feed spout is made of cast iron and has a semi-circle opening or mouth, so as to spray the coal dust up and against the arch wall, where it is ignited and burnt in suspension. This spout is covered with fire brick for protection and the current of air continually passing through it also protects it from burning out. In fact, there is nothing about this system which is not very durable, and this we consider a very important feature. There are slides or valves at different places in the air pipe so as to admit just enough air to get perfect combustion, all of which are under the control of the operator.

As the great drawback to my system for burning powdered coal is the cost of preparing the dust and feeding it to the furnace the following figures, though far from complete, are of interest. We give these figures as stated by the manufacturers:

We have made a careful test under our own boiler with approximate results as follows: On ordinary run of mine coal we use 2,850 lbs. to 3,000 lbs. of coal per day; powdered coal from 2,000 to 2,200 lbs. of coal per day. It has been somewhat difficult lately to procure coal of equal value; on account of the scarcity of coal we have had to get most any kind. Our feeding device with a 4-in. belt probably would not take but 3 HP., and the cost of the drying and grinding our coal does not exceed 8 HP., and in making our test we have always run the grinding and driving machinery when we were using powdered coal and did not use this machinery when we were making a test on the run of mine coal.

The saving will depend entirely upon the waste on the boiler in firing the old way; that is, if the system is a good one the saving will be 25%; with a poor outfit, poor grates, poor firemen, the saving will be at least 50%. The feeder, the fan and the conveyor are all self-contained, all on one frame, and the cost of feeding device complete, that is, the feeder and fan, will not exceed $500 for a single boiler. We also believe that this system is of special value for brick kilns, lime kilns, etc.

No. 2

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